BULLETIN
of CARNEGIE MUSEUM OF NATURAL HISTORY

THE CLARK'S CAVE BONE DEPOSIT AND THE LATE PLEISTOCENE PALEOECOLOGY OF THE CENTRAL APPALACHIAN MOUNTAINS OF VIRGINIA

DEDICATED TO THE MEMORY OF DR. J. KENNETH DOUTT, CURATOR OF MAMMALS, CARNEGIE MUSEUM OF NATURAL HISTORY, FROM 1938 TO 1972

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NUMBER 2 PITTSBURGH, 1977

BULLETIN OF CARNEGIE MUSEUM OF NATURAL HISTORY
Number 2, pages 1-88, figures 1-21, tables 1-23

Issued January 19, 1977

Price: $12.00 a copy

CARNEGIE MUSEUM OF NATURAL HISTORY, 4400 FORBES AVENUE
PITTSBURGH, PENNSYLVANIA 15213

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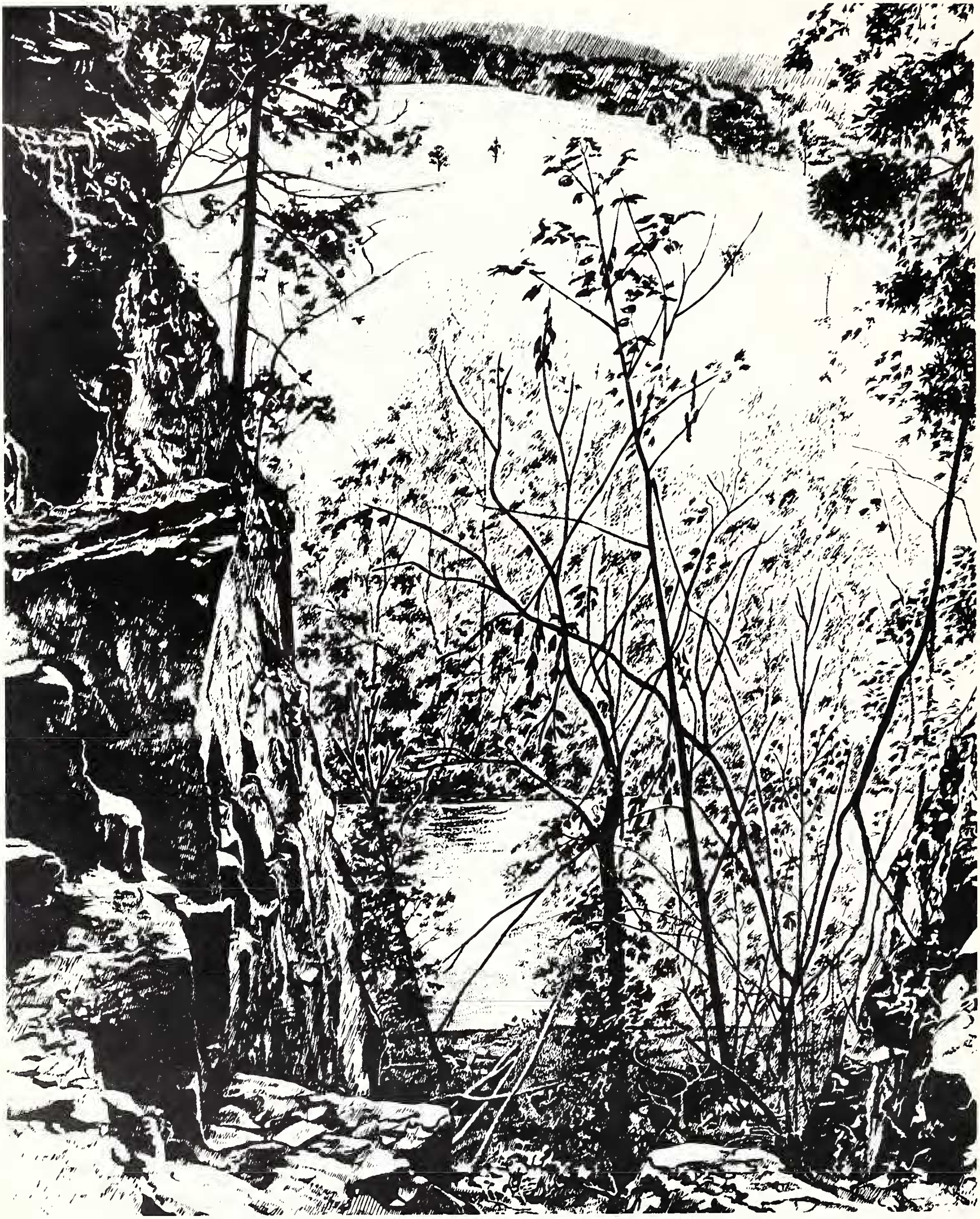

Fig. 1. Looking north from Entrance No. 2, Clark's Cave, Bath County, Virginia, across Cowpasture River. Tower Hill Mountain in background. Fossil deposit in passageway left off photo. Sketch by J. R. Senior from H. Hamilton composite photo.

ABSTRACT

Remains of 142 species of vertebrates, ca 4,984 individuals, and 35 species of invertebrates, ca 5,547 individuals, were recovered from a late Pleistocene "owl roost" in the entrance talus of Clark's Cave in the central Appalachian Mountains, lat. 38°05′10″ N., Bath County, Virginia, U.S.A. Sixty-four percent of the medium-to-small-sized mammals represented in the cave remains are now found either farther north or conform in size to present boreal population equivalents (Bergmann's Response) and with the New Paris No. 4, Pa. local fauna. Deposition took place during late glacial times, > 10,000 years B. P., and ceased before the boreal-to-temperate, post-glacial floral adjustment was completed at the site. Ptarmigan, *Lagopus*, and least chipmunk, *Eutamias*, are added to the late glacial fauna of the Appalachians.

A spruce/pine parkland with nearby bog and meadowlands in a complicated topographical pattern is suggested by the ecological requirements of the faunal components. A contemporaneous mixture of presently allopatric northern, midwestern, and temperate Appalachian species is noted, suggesting a richer ecological picture than was apparent at New Paris No. 4, Pa., 240 km to the north.

Quantitative analysis suggests that several species of raptors were involved. Comparisons with other Appalachian cave and fissure deposits demonstrate the difficulty of ascertaining methods of deposition by faunal analysis only.

INTRODUCTION

THE SITE

Clark's Cave, 12 km southwest of Williamsville, Bath County, Virginia (U.S.G.S. Williamsville quadrangle 15′ series, latitude 38°05′10″ N., longitude 79°39′25″ W.), is located in north-central Virginia on the south bank of the Cowpasture River in the headwaters of the James River drainage (Fig. 2). It is a large cave with a complicated maze of over 2,400 m of cave passages. The six major entrances to the cave occur along a one km strip of high, picturesque, limestone cliff that towers some 30 m above the southern bank of the river. The lower Devonian limestone cliffs, (Helderberg group, New Scotland member (Bick, 1962) form a distinctive feature of the landscape (Figs. 1 and 6). Extensive talus at their base, still active because of steep profile and crumbling cliff, forms a high, rocky tumble, forested, cool and shaded by the northward-facing cliffs. The cliff face and its numerous cave entrances make ideal roosts for birds of prey. Although no raptors nest in the cave entrances today, the barn owl (*Tyto alba*), red-tailed hawk (*Buteo jamaicensis),* and raven (*Corvus corax)* still frequent them as a temporary roost. These cliffs attracted raptors during the late Pleistocene. The extensive bone deposit here reported from entrance No. 2 (Fig. 3) represents but a small portion of a formerly more extensive accumulation of nesting and roosting debris.

Facing north across the Cowpasture River from the large amphitheater of entrance No. 2 (Fig. 1), about 20 m above the river, one looks across approximately 50 m to a gradually rising pasture at about the same elevation (ca. 448 m, or 1,495 ft). One and one-half km beyond, the southern end of Tower Hill Mountain ascends to approximately 840 m (2,800 ft) elevation. Warm Springs Mountain, 6.4 km west of the cave, rises to an elevation of over 1,100 m. About a kilometer up- and down-stream from the cliffs (Figs. 8 and 9) the Cowpasture River broadens considerably, meandering across a flat valley floor, averaging .6 km wide, abruptly bordered by forested hills. These river flats were undoubtedly the source of most of the vertebrate fossils in this vole-dominated assembly. The rock inhabitants probably came from the talus immediately below the cave.

THE DEPOSIT

The fossil deposit, the Clark's Cave local fauna (Field Site No. 3, Figs. 4 and 5), was discovered near the top of a loose, unconsolidated talus feeding down from a passageway that entered the amphitheater of entrance No. 2 from the west (Figs. 4 and 5). Beginning in darkness, this talus cascaded at a 45° angle some 10 m, where it joined the main amphitheater talus fronting the cliffs. When first examined in the spring of 1972, bone fragments were noted throughout the talus accumulation. But the rare coincidence of unusually heavy rains that summer, coupled with a heavy rockfall from the cliff face above, caused a rock slide that removed three-quarters of the fossiliferous matrix. Only that portion that lay at the top of the talus was left intact.

An excavation (Figs. 4, 5 and 7) 2.1 m x 1.4 m x 0.5 m, approximately 3.9 cubic m, was made at the top of the talus in the fossiliferous area. The matrix

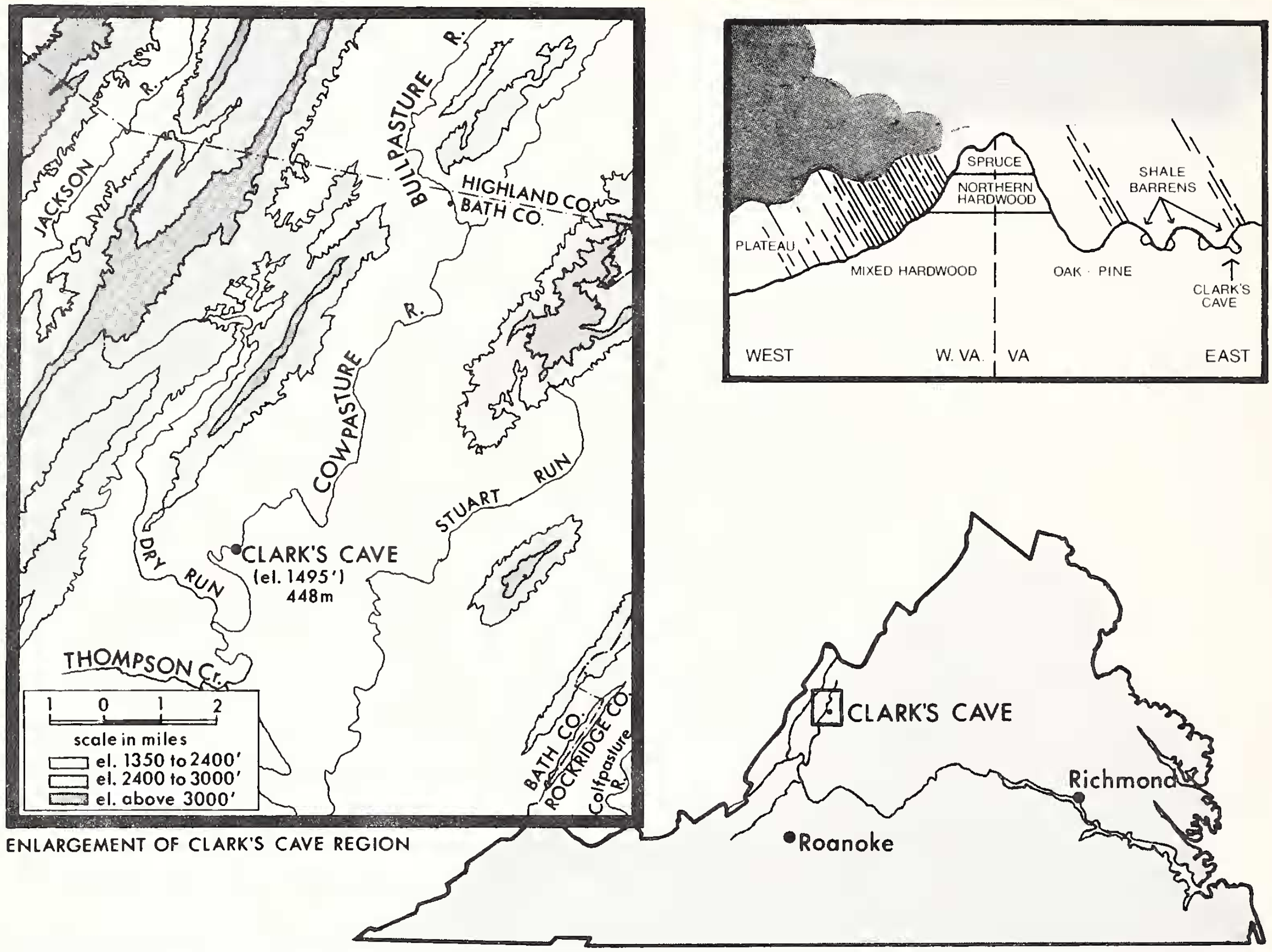

Fig. 2. Site location, Clark's Cave, Bath County, Virginia. Upper right: exaggerated cross-section of mid-Appalachians showing precipitation pattern, modified from Core, 1974.

was 90% cliff-wastage—ungraded, loose, frost-wedged fragments of Helderberg limestone, ranging in size from tiny spalls to large blocks. The remaining 10% consisted of organic remains and a dark-brown, dry soil-like material, probably worked into the raw talus by wind and gravity accretion. Open cracks between the rocks permitted material to filter down through the limits of the talus prior to and during excavation. The detritus varied from 30 cm to 46 cm in depth and rested on sterile cave clay. Organic inclusions (occurring throughout) were seeds, leaves (see floral listing), woodrat droppings, snails, egg-shell fragments, arthropod chitin, and thousands of small bones and teeth. No Recent owl pellets were encountered during excavation. There was no evidence of hair or feathers that occur in Recent owl pellet accumulations. These had apparently decomposed through the years, leaving only a lag deposit of bones and teeth of prey items.

PROCEDURE

Approximately 540 kg of matrix was dry-screened through a 6 mm mesh (1/4-inch hardware cloth) and large items were removed and boxed at the site. One hundred-eighty kg of screen-concentrate was bagged and washed through 1 mm mesh (commercial window-screening) at the New Paris field laboratory. All macroscopic organic inclusions were removed. Further sorting of bones and teeth was carried out at Carnegie Museum under the direction of Helen McGinnis and the senior author, and various categories were submitted to specialists for identification (see *Faunal List*). All specimens, with the exception of a few passenger pigeon remains, are stored in the Section of Vertebrate Fossils, Carnegie Museum of Natural History. Selected pigeon bones are stored in the avian osteology collection, Department of Anthropology, The University of Tennessee at Knox-

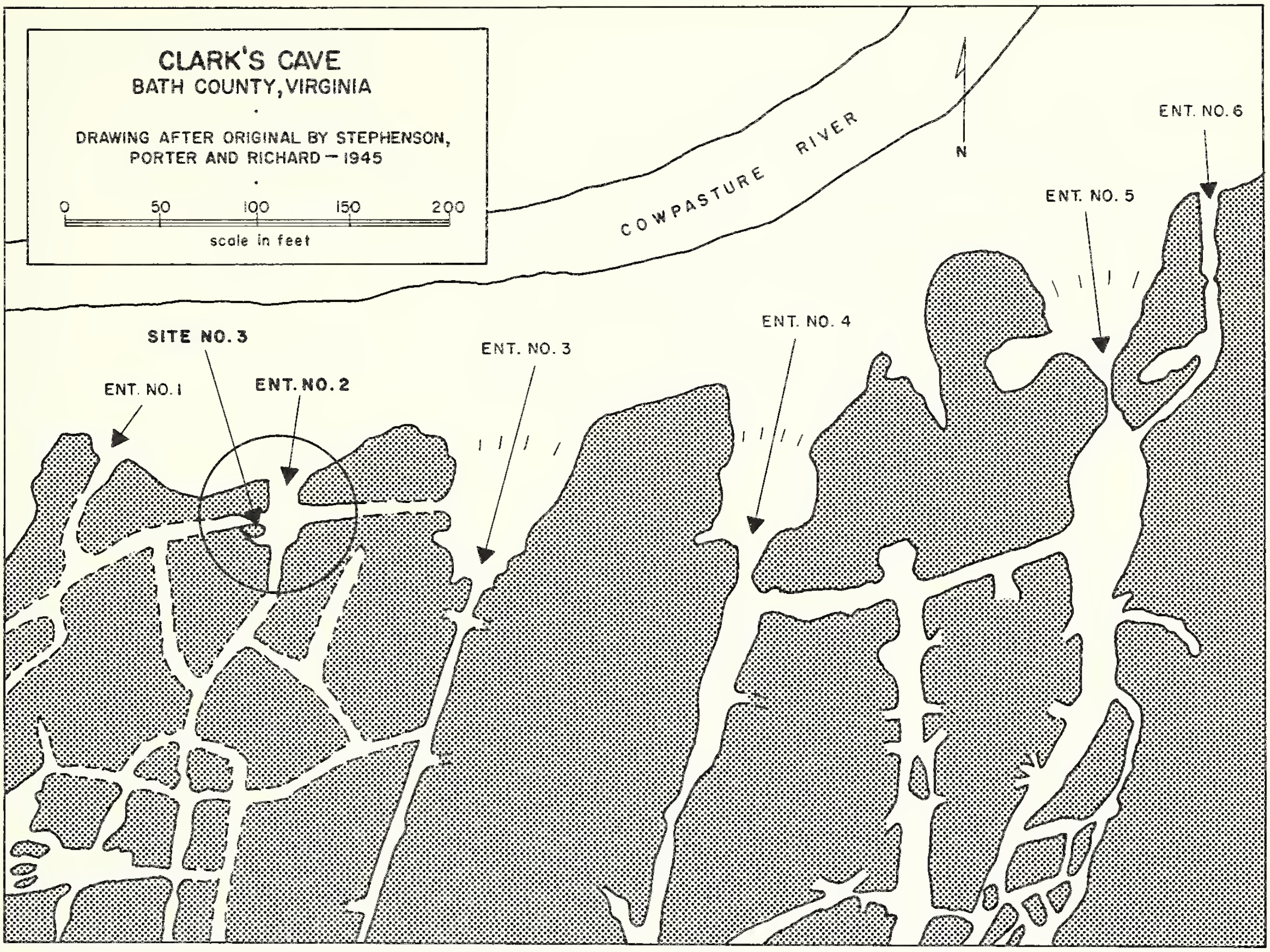

Fig. 3. Map of entrances to Clark's Cave, Bath County, Virginia.

ville. The loose nature of the matrix and its exposed situation made pollen analysis and carbon-14 dating (see *Age of Deposit)* unreliable. A carbon date was run on small mammal bones, and the woodrat droppings were saved for possible pollen content

The three primary study objectives were: 1. Identification to species if possible; 2. Establishment of minimum numbers of individuals for each taxon; 3. Assessment of possible size-differences between fossil and Recent population equivalents. In the case of mammals these objectives were accomplished by studying the dentitions and cranial parts. Mammalian post-cranial material, with a few exceptions like talpid humeri, received only cursory attention. They were not classified or catalogued, but they are stored with the collection. Bird, reptile, amphibian, and fish identifications were based primarily on postcranial elements.

The minimum number of individuals of each species (MNI) was established by the highest replication of any diagnostic elements—tooth, limb bone, etc. These elements differed from species to species. The voles, for example, were represented primarily by isolated teeth and partial maxillae and dentaries. Approximately 17,000 isolated arvicolid molars were recovered from the screen washings. Individual molars were specifically identified, then tallied according to their serial position, first, second, third molars, whether upper or lower, right or left. These categories were then tallied and the greatest number for any given tooth was considered the minimum number of individuals represented for that particular species. The same procedure utilizing various skeletal parts was employed for the entire vertebrate collection. Elements utilized are listed under materials in the individual species accounts.

Preservation of bones and teeth was chemically excellent, but mechanically poor. Bone appeared

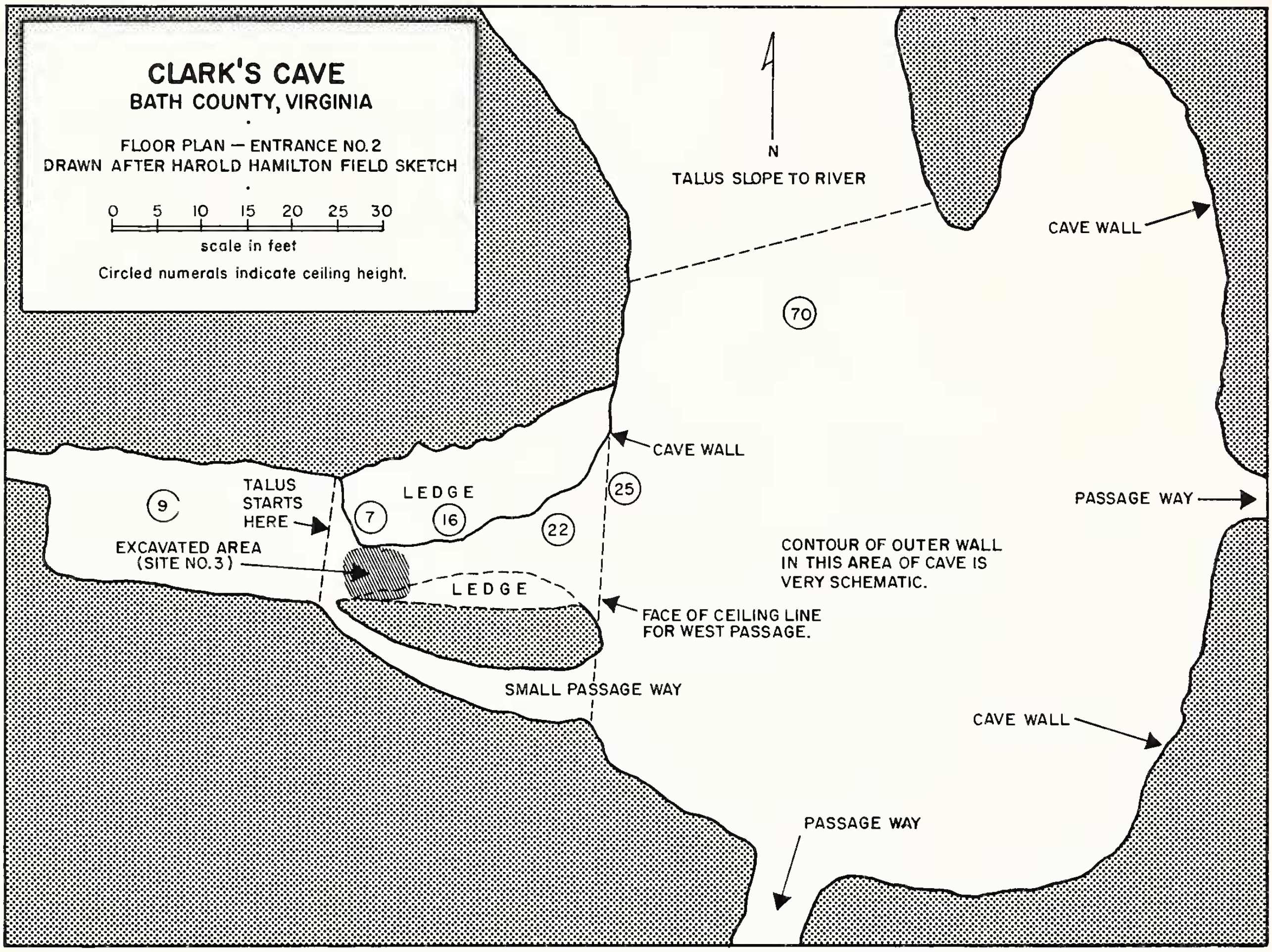

Fig. 4. Excavation plan, Entrance No. 2, Clark's Cave, Bath County, Virginia from above.

unaltered and frequently could not be distinguished from Recent owl pellet material from the area. Some specimens did have a thin carbonate crust, but none were fused. Bones, shells, and egg shells were badly broken, often ground to fragments on the sharp rock matrix by talus creep and excavating and recovery procedures. Very small specimens—shrew and bat dentaries, small molluscs—fared best, but larger objects were invariably badly fractured. Teeth, large or small, were usually separated from skull parts. No articulated remains were found. Size sorting was not present and all bone distribution, both horizontal and vertical, in the deposit appeared to be random.

Measurements less than one centimeter were taken with the aid of a Spencer Cycloptic stereoscopic microscope, using an ocular grid at 10 X. The particular instrument used (No. 4451931) required a correction factor of 0.97 to convert ocular measurements to true millimeters at that magnification. Larger measurements were taken with a dial micrometer calibrated to 0.1 mm.

Responsibility for various sections are as follows: geology and site mapping, Hamilton; birds, Parmalee; mammals, Guilday. Remaining sections are by Parmalee and Guilday jointly. Specialists involved in identifications are listed in *Acknowledgements* and in the faunal list.

To avoid repetition, previously reported bone sites are not cited in the text. References may be found in Table 23 (site references).

Avian nomenclature follows the A.O.U. *Checklist of North American Birds* (5th edition) and its 32nd supplement (Auk 90:411-419). Mammalian nomenclature is largely from Jones, Carter, and Genoways, 1975.

The bird bones from Back Creek Cave No. 2, Bath Co., Virginia, are included in the inventory of bird remains, but are catalogued and listed separately

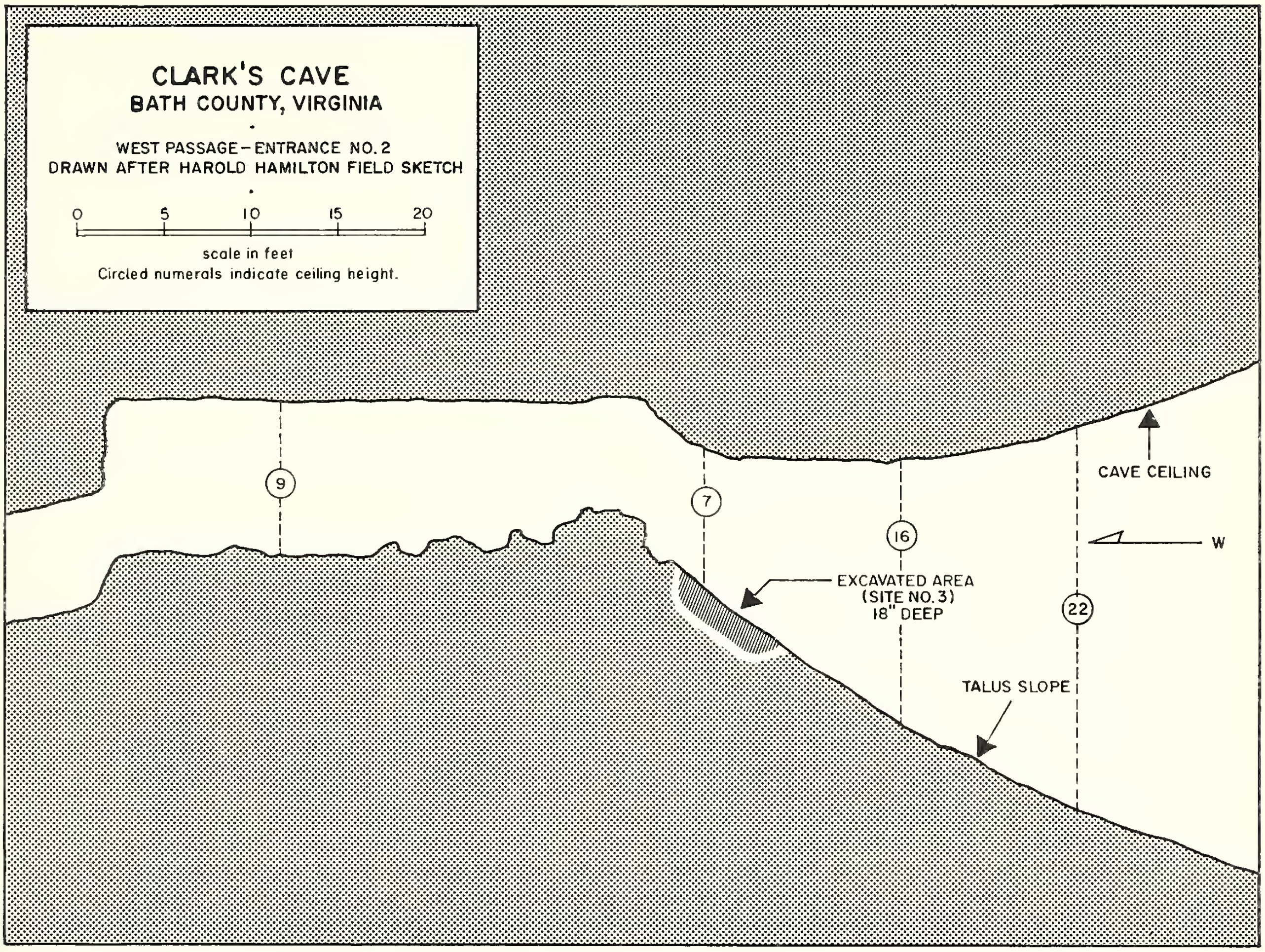

Fig. 5. Excavation plan, Entrance No. 2, Clark's Cave, Bath County, Virginia vertical section.

under appropriate species. This site, a shallow "rock shelter" 24 km west of Clark's Cave, is a late Pleistocene owl roost deposit similar to that at Clark's Cave. Most of the mammals have not yet been studied as of this time, but the faunal make-up of the two sites appears to be similar.

ABBREVIATIONS

AMNH—American Museum of Natural History; B.P.—before present; ca—approximately; CM & CMNH—Carnegie Museum of Natural History; cm—centimeters; CV—coefficient of variation; g—grams; I—Isotopes, Inc.; kg—kilograms; km—kilometers; m—meters; MNI—minimum number of individuals; N—sample size; OR—observed range; SD—standard deviation; SI—Smithsonian Institution; USNM—United States National Museum; SIU—Southern Illinois University; $\bar{X}$—arithmetic mean; > —greater than. Capital and lower-case letters followed by online numbers [C/c (canine), P/p (premolar), M/m (molar)] refer to upper and lower teeth, e.g., M1,m1.

ACKNOWLEDGMENTS

We are indebted to many people who contributed services and expertise to this project, and take great pleasure in acknowledging their assistance. Mrs. W. G. Clark, the owner of Clark's Cave, kindly allowed us to excavate and collect on her property. Able assistance during excavation and field screening was provided by Lee Ambrose, Alan Bailey, Mr. and Mrs. Nevin C. Davis, Karen Downing, Gwen Foster, Mary Ann Gross, Rita and Allen Hamilton, Paul, Helen, and Mimi Imblum, Mr. and Mrs. William King, and Mr. and Mrs. Robert New. Processing of matrix at the New Paris field laboratory under the co-direction of Allen D. McCrady and Harold W. Hamilton involved so many willing volunteers that space permits only a general, but warm thank-you to all. Helen

McGinnis deserves our special thanks for her many months of laboratory sorting and for the study and identification of the anuran remains.

We thank our many colleagues for their assistance: *Plants:* Fel Brunett, Chippewa Nature Center, Midland, Mich. *Molluscs:* Leslie Hubricht, Meridian, Miss.; Dr. William J. Clench, Harvard University. *Decapods:* Dr. Horton H. Hobbs, Jr., USNM. *Insects:* Dr. Everett D. Cashatt, Illinois State Museum. *Fish:* T. N. Todd and Dr. Robert R. Miller, University of Michigan. *Reptiles and amphibians:* Dr. Clarence J. McCoy, Jr., CMNH. *Birds:* Dr. Mary H. Clench and Dr. Kenneth C. Parkes, CMNH; Dr. Storrs L. Olson, Dr. Richard L. Zusi, and Dr. Alexander Wetmore, USNM; Dr. Amadeo M. Rea, University of Arizona, Tucson. *Mammals:* Dr. Elaine Anderson, Denver; Caroline A. Heppenstall, Dr. J. K. Doutt, and Dr. Duane A. Schlitter, CMNH; Dr. Karl Koopman, AMNH; Dr. E. C. Galbreath, SIU; Wayne E. Clark, Assistant Archaeologist, Virginia State Library (who supplied archaeological data). Illustrations are by Erica Hanson (Fig. 19), James R. Senior (Figs. 1 - 5, 16) and Nancy Perkins (Figs. 11 - 15, 17, 18, 20, 21). Elizabeth Hill, Wendy Pollock, Kathleen Guilday, Albert Kollar, and Ronald Wilson provided laboratory or clerical assistance. We wish to thank Dr. Mary R. Dawson, CMNH, Dr. Charles O. Handley, Jr., USNM, and Dr. Holmes A. Semken, University of Iowa, for reviewing the manuscript. Dr. Handley also surveyed the Recent small mammals from the area, and we thank him for his many notes on the Recent vegetation, birds and mammals of the cave area, and for the loan of specimens. The authors are indebted to their wives, Alice, Barbara, and Rita, for things innumerable. Research was conducted under NSF Grant No. GB 42258, awarded to the senior author.

REGIONAL SETTING

The Cowpasture River rises in the central Appalachian Mountains. It meanders southwestward for some 72 km in an intermontane valley to join the James River, which flows east 400 km to the Atlantic Ocean. For most of its length, the valley of the Cowpasture River is broad and flat, averaging perhaps 0.8 km in width. In Bath County, Tower Hill Mountain, rising to 970 m, borders the northwestern side of the valley. The mountain crest follows an anticlinal ridge of the resistant Middle Silurian Clinton Formation, a heterogeneous mixture of sandstones and shales. The southeastern rim of the valley is formed by Shenandoah Mountain, a resistant synclinal core of Upper Devonian Chemung sands and conglomerates. The river follows the more easily eroded trough between these mountains. Sixteen km northeast of the cave Shenandoah Mountain rises to over 1,060 m but loses altitude to the south. Approximately two km directly south of the cave, a dissected range of hills, “the spurs,” rises to 760 m.

About 1.5 km upstream from Clark’s Cave, the river, flowing along the flat valley floor (Figs. 9 and 10), has worn through the structurally older Ridgeley sandstone and flows through an abruptly tightened valley, narrow and precipitous, carved out of the underlying Lower Devonian Helderberg limestone. The Cowpasture valley retains this gorgelike character past the cave mouth and for another km downstream, where the valley suddenly broadens again (Fig. 8) as the river emerges once more into shale lands.

High mountainous country west of the Cowpasture River valley, rising to over 1,000 m, diverts much of the moisture from the prevailing westerlies, and the valley lies within their rain shadow. This produees a mild xeric effect that has resulted in the formation of a distinct topographically and botanically defined provincial subdivision: the shale barrens. Shale barrens occur along the crests of low shale hills that lie just to the east of the plateau country, from southern Pennsylvania to southern Virginia (Keener, 1970).

The present climate of the area is temperate and mild. Observations over a forty-year period at Hot Springs, Bath County, 20 km southwest of the cave, show a temperature range from 36.7° to -28.9° C. (98° to -20° F.) with a January average of 0.2° C. (32.4° F.), and a July average of 20.8° C. (69.5° F.). There is no definite wet or dry season, but precipitation at Hot Springs is highest in June and lowest in January, with a yearly average of 105 cm. The weather is controlled by a succession of cyclonic pressure cells from the west, with (especially in the summer months) warm, moist air masses from the Caribbean, resulting in a varied day-to-day climatic pattern. Western Virginia is too far inland for its climate to be directly affected by the Atlantic Ocean except during rare hurricane phenomena. Winters are generally mild, except in the mountain and plateau highlands. Yearly snowfall averages 63.5 cm and usually does not provide continuous winter cover (Hibbard, 1941).

Just prior to Colonial settlement, the area surrounding the cave was completely forested with an oak-dominant vegetation (Braun, 1950; Hack & Goodlett, 1960; Clarkson, 1966; Core, 1974). The slope on which the cave is located was undoubtedly covered, then as now, with a mesic Appalachian cove forest: hemlock *(Tsuga)*, arborvitae *(Thuja)*, tulip poplar *(Liriodendron)*, and basswood *(Tilia)*. This same forest is found in gorges on Tower Hill Mountain and Warm Springs Mountain, west of the cave. The nature and composition of the forest is in subtle concordance with local variations in elevation, exposure, drainage patterns, and soils. As a general rule, valley floors and higher mountain summits receive the most moisture, the former from precipitation plus slope drainage, the latter through precipitation alone. Valley floors of the area originally were covered with a white-oak *(Quercus alba)*-dominant forest, while the dryer mountain slopes were covered with a chestnut/chestnut-oak *(Castanea/Quercus primus)*-dominant forest. In higher, moister, mountainous areas, and especially in high valley heads, the forest became richer in species of maple *(Acer)* and birch *(Betula)*.

Spruce *(Picea)*-dominated woodland occurs, or did occur, on many of the higher summits to the west, but not near the Cowpasture River valley. The distinctive shale barrens, open woodlands of low scrub oak *(Quercus ilicifolia)* and pines *(Pinus, spp.)* with much bare ground, occupy the low hills bordering the southeastern rim of the valley (Fig. 9), forming a distinct biotype characterized by many low-order plant endemics. The shale barrens appear today as a distinct, open, mildly xeric habitat. They would certainly have been in the cruising range of the Clark's Cave raptors if they were in existence during the late Pleistocene. The presence of plant endemics argues that the barrens are at least that old, and they may have supported some of the Midwestern forms present in the deposit, like the sharp-tailed grouse *(Pedioectes phasianellus)*, the least chipmunk *(Eutamias minimus)*, and the thirteen-lined ground squirrel *(Spermophilus tridecemlineatus)*.

The floor of the Cowpasture River valley, like that of the broad Shenandoah valley to the east, lies within the Carolinian Life Zone (Dice, 1943). This zone occupies the valley floors of western Virginia up to about 460 m and ascends to 600 m in open country. Its upper limit may dip as low as 370 m, however, in forested ravines (Murray, 1945). All the mountain ridges, with the exception of a few summits above 1,200 m, lie in the Alleghenian or Transition Zone. According to Murray, the theoretical upper limits of the Alleghenian Life Zone should lie between 915 m and 1,070 m in Virginia. But biological zonation is not a simple function of altitude. It varies with slope exposure, air drainage, local precipitation, and soil characteristics. Zones merge gradually, and the upper limits of the Transition Zone in the Virginia and West Virginia mountains range from 1,000 m (Cranberry Glades, W. Va.) to 1,364 m (Elliott's Knob, Va.). Areas of Canadian Zone, spruce-dominated flora top a few of the higher peaks.

"While there is a good deal of Canadian Zone territory in the high Allegheny Plateau of West Virginia [700,000 acres before logging, Brooks, 1943, p. 25], and a fair area of it on the great peaks of the Smokies along the North Carolina and Tennessee line there is little or no territory in Virginia which can be called pure Canadian. On White Top and Mt. Rogers, the two highest mountains in Virginia which reach 5,519 [1,672 m] and 5,720 feet [1,723 m] respectively, we have some small areas which are practically Canadian, and on Middle Mountain in Highland County we have some territory that approaches it." (Murray, 1945 : 20) After logging, the Canadian Zone spruce stands are replaced by Transition Zone mixed hardwood/coniferous forest.

It can be seen that great topographic and biotic diversity, ranging from mountain tops to valley floors, and great variations in subsurface water, ranging from the xeric shale hills of the shale barrens to river flood plains, were present within the cruising range of the Clark's Cave raptors. Thus the interpretation of the fossil fauna from a regional point of view is complicated.

HISTORY OF SITE

The history of man's occupation of the Cowpasture River valley may be related to the age of the fossil deposit. Unmolested, the nesting of birds of prey at the site could proceed with little interruption. But the arrival of man in the valley may have brought nesting to an end because the former raptor roost at entrance No. 2 was easily accessible from the river. The fauna recovered from the site suggests that deposition ceased prior to the establishment of the modern regional biota about 10,000 to 11,000 years ago, and current archaeological evidence suggests that paleo-Indian occupation of western Virginia extended at least that far back in time. No direct evidence of such an early occupation has been recorded from the Cowpasture valley, but an important paleo-Indian complex, the Thunderbird Site (44 WR 11) (Gardner, 1974), is known from the Shenandoah valley, about 70 km to the east. This site, on an alluvial fan of the South Fork Shenandoah

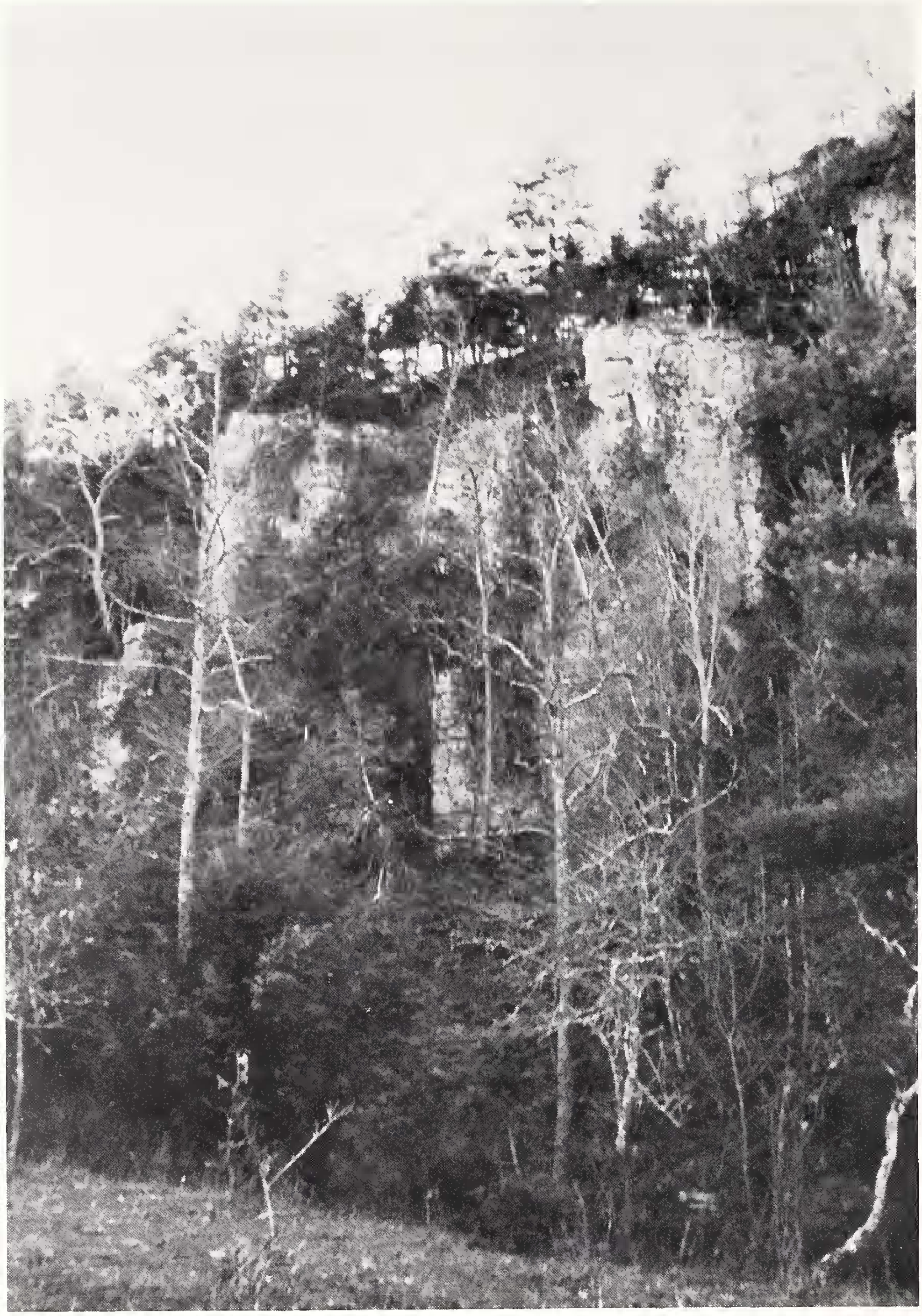

Fig. 6. View looking southeast, from across Cowpasture River, at Clark's Cliffs, early Devonian Helderberg limestone. Entrance No. 2 and fossil site off photo to right. Note active, wooded talus. Hamilton photo.

Fig. 7. Mary Ann Gross (lower left) on excavation site in unconsolidated talus of west passage, Entrance No. 2, Clark's Cave, Bath County, Virginia.

Fig. 8. Cowpasture River, 2 kilometers downstream from Clark's Cave, Bath County, Virginia. Cave is behind hill to right. Note V-shaped gorge as river traverses Helderberg limestone, and flat valley floor as it emerges into shale lands.

River, is centered around an aboriginal jasper quarry from which paleo-Indian hunters periodically refurbished their tool kits. The easy access to Clark's Cave roosts may have invited exploitation and disruption at an early date, forcing the birds to seek more secure nesting sites.

Four prehistoric archaeological sites in the Cowpasture River valley itself are recorded in the Virginia State Library archaeological survey site records (site nos. 44 HL 12, 44 HL 14, 44 BA 1, 44 BA 36). One, 44 BA 1, is in a setting quite similar to the Clark's Cave cliffs. It is a rockshelter in a small gorge formed where the Cowpasture River traverses a tongue of Devonian limestone that crosses the river valley 13 km down stream from Clark's Cave. Other small Indian campsites are recorded from the nearby Bullpasture and Jackson River valleys (MacCord, 1973a, 1973b).

The valley was surveyed in the early 1740's following a short period of Indian wars, and permanent European settlement began. Timber was cleared first in the valley floor and then in the surrounding mountains. The valley soon became a farming and livestock area. The cave became the site of a thriving saltpeter industry established to satisfy the demand for the substance in gunpowder manufacture. Clark's Cave is reputed to have had over 200 men mining cave earth (Faust, 1964). With the decline of the saltpeter industry at the close of the Civil War in 1865, the site was left relatively undisturbed. It was surrounded by farming activities and was occasionally visited by the public. It later beeame a popular resort of weekend cave explorers, but was closed to caving in 1973.

In summary, Clark's Cave and the Clark's cliffs have been exposed to potential human exploitation for at least the past 10,000 years. Any evidence of an actual Indian occupation at any of the entrances of

Clark's Cave would have been destroyed by mining activities, and we are indeed fortunate that site No. 3 was not destroyed as well. Only its location, perched high on a talus slope in a dead-end passage, preserved it.

CLARK'S CAVE RAPTORS

The fossil bone deposit accumulated in the twilight zone of the cave around the roosts and nests of carnivorous cliff/cave-frequenting birds, primarily owls. The bulk of the deposit represents prey collected from the neighboring environs and is the result of the build-up of food debris, primarily owl pellets, through the course of many years. The variety of prey, nocturnal and diurnal, field and forest, vertebrate and invertebrate, argues for not one, but probably many species of birds of prey. Owls, hawks, eagles, vultures, ravens—all cliff-frequenting species—may have contributed at one time or another to the deposit. Raptor bones actually recovered included those of two accipiters, one falcon, and three owls—the great-horned, *Bubo virginianus*; the long-eared owl, or short-eared owl, *Asio,* sp.; and saw-whet owl, *Aegolius acadicus,* the latter possibly a prey item.

Large owls like the snowy owl, *Nyctes scandiaca,* and the great-horned owl prefer larger game than do smaller species like the short-eared owl; the barred owl, *Strix varia;* or the barn owl, *Tyto alba.* When the prey items of the Clark's Cave deposit are classified according to the size of the living animals, the collection resembles that of the prey of medium-sized field-hunting owls, the barn owl, and the short-eared owl (Table 1). Mammals of rabbit size or larger comprised only 0.5% of all prey items analyzed. This accords with the figures for the medium-sized owls. In the larger barred owl, rabbits increase to 6.5%; in the still larger snowy and great-horned owls, from 24% to 46%. They are unrepresented in the diet of smaller species like the screech owl, *Otus asio.*

The candidates most likely to be responsible for the bulk of the deposit are the eared owls (*Asio,* sp.) and the barn owl. The high percentage of field forms in the deposit, primarily voles of the genus *Microtus,* suggests a predator that hunts in open country, like the barn owl and the short-eared owl. Basically the short-eared owl *(A. flameus)* is an open grassland-roosting bird, while the long-eared owl *(A. otus)* is a pine/brush thicket-roosting species.

Table 1. Diet of various owls from eastern North America.[1]

Species	Owl total length	% Rabbit class	% Squirrel class	% Mice class	% All bird	N
Nyctea scandiaca snowy owl	20"	24.0	12.0	20.0	39.0	251
Bubo virginianus great horned owl	20"	46.0	11.0	33.0	17.0	2,714
Strix varia barred owl	17"	6.5	7.0	78.0	8.0	521
Tyto alba barn owl	14"	.1	1.2	95.0	1.4	8,151
Asio otus long-eared owl	13"	.5	.3	94.0	2.4	2,112
Asio flammeus short-eared owl	13"	.3	5.0	93.0	2.0	263
Aegolius funereus boreal owl	10"	——	——	93.0	7.0	15
Otus asio screech owl	8"	——	——	83.0	6.0	73
Aegolius acadicus saw-whet owl	7"	——	——	96.0	4.0	21
owl, ?species Clark's Cave, sample Pleistocene	——	.5	2.8	95.0	2.2	4,562

[1]N = Stomach/pellets examined except for Clark's Cave, where it indicates minimum number of animals in fossil prey population. Raw data from Latham, R.M., 1950.

Fig. 9. Mildly xeric shale barren habitat on low shale hills of southern side of Cowpasture River valley. Fig. 10 taken from same spot. Right edge of photo overlaps left edge of Fig. 10.

The barn owl is associated primarily with the Carolinian Life Zone. It occurs no farther north than southern New York State, and avoids the higher portions of the Appalachian Mountains. It does occur at the site today. Both feathers and fresh pellets were picked up along the cliff face by Parmalee in July 1974. The predominantly boreal character of the fossil-prey species, many of which do not occur in the Appalachians today, reflecting the effects of the Wisconsinan glaciation, do not appear to be likely barn owl prey, given the present ecological requirements of that species. If the long-eared owl inhabited the cave it could have been responsible for a large portion of the boreal meadow voles in the deposit. It is possible, however, that the barn owl, despite its modern temperate range, may have inhabited the cave during the late Pleistocene.

Small egg-shell fragments were distributed randomly throughout the deposit. Dr. Mary H. Clench compared them with modern eggs from the CMNH collections, but they could not be identified with certainty. At least some of the fragments appear to be from birds of large size e.g., eagle or vulture.

In summary, the Clark's Cave fossil deposit represents nest debris of some medium-size owl, or owls, with additions from other raptorial species throughout its long depositional history.

QUANTITATIVE ANALYSIS

All birds and small mammals recovered from the fauna are Recent species, so that the Clark's Cave fossil fauna can be expressed quantitatively by the cumulative body weights of the 114 species of birds and mammals considered to be raptor prey. The relative contribution to the raptor diet of the various

Fig. 10. Oak (*Quercus*)-forested hills along northern side of Cowpasture River valley, 2 kilometers upstream from Clark's Cave, Bath County, Virginia. Note broad flood plain, probable source of many of the fossil voles from the cave deposit. Cave out of sight around far left hill. River flows along base of forested hills from right to left.

species or species groups represented can be ascertained. Average live weight of individuals of each species considered raptor prey (Faunal List, Table 4) was multiplied by the minimum number of individuals of that species recovered. The resulting cumulative weights had little meaning as far as expressing actual totals consumed or the true relative caloric value of each species in the raptor diet, because of the many variables involved. But when these figures are compared, they give some indication of relative contributions to the raptor diet. Weights were obtained from the literature and represent average approximations. Various authorities did not always agree. Mammal weights were taken from Banfield, 1974, Doutt *et al.*, 1973, and Youngman, 1975. Bird weights were furnished by Dr. Kenneth Parkes, who stresses that "average" figures, especially for birds with great sexual weight disparity, like the turkey or sharp-shinned hawk, are rough indeed. Despite the unavoidable crudeness of the analysis, trends emerge that probably parallel the true picture.

The total estimated biomass represented by the recovered fossils was 277.82 kg, 73.5% (204.31 kg) mammal remains, 26.5% (73.51 kg) birds. Results are summarized in Table 2 by families. Voles (Arvicolidae) contributed most heavily both in terms of individuals (45.2%) and in terms of body weight (36.6%). Although birds accounted for only 4.6% of the combined numbers of individual birds and mammals, grouse (Tetraonidae) accounted for 13.6% of the estimated biomass, ranking second only in importance to the voles.

Bats, ranking second in terms of individual animals recovered (34.0%), contributed only 5.5% to the estimated biomass. Voles, rabbits and hares (Leporidae), and grouse accounted for 63% of the estimated biomass. Other small rodents (Cricetidae, Sciuridae, Zapodidae) comprised an additional 15%. Although there were more species of birds than mammals, they—with the exception of grouse, pigeons (Columbidae), and ducks (Anatidae) contributed little to the raptor diet.

In terms of biomass, hares ranked third (Table 2) because of their high individual body weight, but they contributed only 0.5% of the number of individual birds and mammals recovered. Of the 15 most common species, in terms of numbers of individuals recovered from the site (Table 3), not a single bird ranked. Eight species of small rodents, 4 bats, and 2 shrews (12.5% of the 120 species of birds and mammals from the site) accounted for 86% of the 4,555 individuals recovered.

In summary, the deposit was overwhelmingly composed of small rodents and bats, and in terms of individuals, all other species found were present in incidental numbers. But in terms of biomass, voles, grouse, and hares were most important in their contribution to the avian diet.

Table 2. Biomass and minimum numbers of individuals from Clark's Cave.[1]

Estimated live weight			Numbers of individuals		
Family	kg	%	Family	Individuals	%
1. Arvicolidae – voles	101.59	36.6	1. Arvicolidae – voles	2,060	45.2
2. Tetraonidae – grouse	37.78	13.6	2. Vespertilionidae – bats	1,554	34.0
3. Leporidae – hares	35.47	12.8	3. Cricetidae – deer mice and wood rats	272	5.9
4. Cricetidae – deer mice and wood rats	23.10	8.3	4. Soricidae – shrews	231	5.0
5. Sciuridae – squirrels	19.93	7.2	5. Sciuridae – squirrels	117	2.5
6. Vespertilionidae – bats	15.22	5.5	6. Tetraonidae – grouse	75	1.6
7. Columbidae – pigeons	9.00	3.2	All others (42 families)	253	5.5
8. Anatidae – ducks	8.54	3.1			
All others (40 families)	27.19	9.7			

[1]Avian and mammalian families ranked in order of representation.

Table 3. Fifteen most abundant vertebrates[1] in Clark's Cave.

Species	Individuals	%
1. *Myotis lucifugus/sodalis/keenii* – little brown bats	c. 877	19.3
2. *Microtus pennsylvanicus* – meadow vole	c. 658	14.5
3. *Microtus xanthognathus* – yellow-cheeked vole	511	11.2
4. *Eptesicus fuscus* – big brown bat	363	8.0
5. *Clethrionomys gapperi* – red-backed vole	305	6.7
6. *Microtus chrotorrhinus* – rock vole	c. 292	6.4
7. *Microtus pinetorum* – woodland vole	170	3.7
8. *Myotis leibii* – Leib's bat	c. 138	3.0
9. *Myotis grisescens* –gray bat	c. 138	3.0
10. *Peromyscus maniculatus* – deer mouse	c. 117	2.6
11. *Peromyscus leucopus* – white footed mouse	c. 104	2.3
12. *Blarina brevicauda* – short-tailed shrew	97	2.1
13. *Sorex cinereus* – masked shrew	67	1.5
14. *Synaptomys borealis* – northern bog lemming	61	1.3
15. *Phenacomys intermedius* – heather vole	34	0.1
104 additional species	618	14.3

[1]Ranked by numbers of individuals.

Table 4. Plant and animal remains, Entrance 2, Site 3, Clark's Cave.

Scientific name	Common name	MNI	
FLORA[1]			
(Identified by F. Brunett)			
1. *Tsuga* cf. *canadensis*	hemlock	----	needles
2. *Thuja occidentalis*	arbor vitae	----	branchlets, seeds
3. *Carya*, ?species	hickory	----	nut fragment
4. *Quercus*, ?species	oak	----	acorn fragment
5. *Celtis occidentalis*	hackberry	c. 150	seeds
6. *Phytolacca decandra*	pokeweed	c. 35	seeds
7. *Vitis*, ?species	grape	12	seeds
8. *Nyssa sylvatica*	black gum	9	seeds
CRUSTACEA			
(Identified by H.H. Hobbs, Jr.)			
1. *Cambarus* cf. *bartonii*	crayfish	4	
2. *Cambarus* cf. *longulus*	crayfish	2	
INSECTA[1]			
(Identified by E.D. Cashatt)			
1. *Dicaelus*, ?species	Carabid (ground) beetle	1	
2. *Galerita* cf. *bicolor*	Carabid (ground) beetle	1	
3. *Calasoma*, ?species	Carabid (ground) beetle	2	
Carabidae, ?species	Carabid (ground) beetle	9	
4. *Onthophagus* cf. *janus*	scarab beetle	5	
Onthophagus, ?species	scarab beetle	1	
5. *Canthon*, ?species	scarab beetle	1	
6. *Balbocerosoma*, ?species	scarab beetle	1	
7. *Trox*, ?species	trogid (hide) beetle	1	
8. Elateridae, ?species	elaterid (click) beetle	1	
Coleoptera, ?species	beetles, unidentified	6	
9. Membracidae, ?species	leafhopper	1	
10. Calliphoridae or Sarcophagidae	fleshflies	pupae	
11. Vespidae, ?species	social wasps	2	
GASTROPODA[1]	Snails	4,363	
(Identified by L. Hubricht and W.J. Clench)			
1. *Hendersonia occulta*	land snail	2	
2. *Vallonia costata*	land snail	5	
3. *Gastrocopta armifera*	land snail	1	
4. *Gastropoda contracta*	land snail	1	
5. *Vertigo tridentata*	land snail	3	
6. *Vertigo gouldi*	land snail	3	
7. *Columella simplex*	land snail	1	
8. *Catinella*, ?species	land snail	1	
9. *Anguispira alternata*	land snail	5	
10. *Discus catskillensis*	land snail	7	

[1]Not considered owl prey.

Table 4. Plant and animal remains, Entrance 2, Site 3, Clark's Cave (continued).

Scientific name	Common name	MNI
GASTROPODA (continued)		
11. *Helicodiscus parallelus*	land snail	12
12. *Helicodiscus inermis*	land snail	2
13. *Helicodiscus jacksoni*	land snail	2
14. *Stenotrema hirsutum*	land snail	3
15. *Stenotrema fraternum*	land snail	1
16. *Triodopsis burchi*	land snail	1
17. *Triodopsis vulgata*	land snail	1
18. *Triodopsis juxtidens*	land snail	5
19. *Strobilops labyrinthica*	land snail	7
20. *Spirodon carinata*	freshwater snail	c. 4,300
BIVALVIA[1]	Clams	140
(Identified by W.J. Clench)		
1. *Sphaerium striatinum*	fingernail clam	1
2. *Pisidium dubium*	fingernail clam	139
OSTEICHTHYS	Bony fishes	57
(Identified by J.E. Guilday)		
1. *Anguilla* cf. *bostoniensis*	American eel	1
2. *Esox* cf. *americanus* or *niger*	pickerel	1
3. *Semotilus* cf. *corporalis*	creek chub	
4. *Nocomis* cf. *raneyi*	river chub	26
Cyprinidae, unidentified	unidentified minnows	
5. *Catostomus*, ?species	white sucker	
6. *Moxostoma*, ?species	redhorse sucker	18
Catostomidae, unidentified	sucker	
7. *Noturus*, ?species	stonecat	11
Ictaluridae, unidentified	small catfish	
AMPHIBIA	Frogs, toads, salamanders	328
(Identified by H. McGinnis)		
1. *Bufo* (*americanus* group)	toad	141
2. *Hyla* cf. *crucifer*	peeper	20
3. *Rana* cf. *catesbiana*	bullfrog	5
4. *Rana* cf. *clamitans*	green frog	2
5. *Rana* cf. *pipiens*	leopard frog	22
6. *Rana* cf. *palustris*	pickerel frog	22
7. *Rana* cf. *sylvatica*	wood frog	42
Rana, unidentified	frog	38
8. *Ambystoma*, ?species	mole salamander	c. 4
9. Plethodontidae or Salamandridae	salamander	c. 32
REPTILIA	Reptiles	37
(Identified by J.E. Guilday)		
1. cf. Testudinidae	turtle	1

Table 4. Plant and animal remains, Entrance 2, Site 3, Clark's Cave (continued).

Scientific name	Common name	MNI	Gram live weight	Total gram live weight
REPTILIA (continued)				
2. *Sceloporus* cf. *undulatus*	fence lizard	13		
3. *Eumeces* cf. *laticeps*	broadheaded skink	2		
4. Colubridae, ?species	non-poisonous snake	c. 20		
5. Crotalidae, ?species	rattlesnake or copperhead	1		
AVES	Birds	219		
(Identified by P.W. Parmalee)				
1. *Podilymbus podiceps*	pied-billed grebe	2	135	270
2. *Botaurus lentiginosus*	American bittern	1	475	475
3. *Anas* cf. *platyrhynchos* or *rubripes*	mallard or black duck	2	1,160	2,320
4. cf. *Anas crecca*	green-winged teal	1	350	350
5. cf. *Anas discors*	blue-winged teal	1	400	400
6. *Lophodytes cucullatus*	hooded merganser	2	610	1,220
7. *Mergus*, ?species	merganser	1	c. 750	c. 750
Anatidae, ?species	ducks, unidentified	5	c. 700	c. 3,500
8. *Accipiter striatus*	sharp-shinned hawk	1	135	135
9. *Buteo* cf. *platypterus*	broad-winged hawk	1	400	400
Accipitridae, ?species	hawks, unidentified	2	c. 575	c. 1,150
10. *Falco sparverius*	American kestrel	2	115	230
11. cf. *Canachites canadensis*	spruce grouse	14	470	6,580
12. *Bonasa umbellus*	ruffed grouse	16	510	8,160
C, canadensis or *B. umbellus*	spruce or ruffed grouse	c. 30-35	c. 490	17,150
13. *Lagopus* cf. *mutus*	rock ptarmigan	1	450	450
14. cf. *Pedioecetes phasianellus*	sharp-tailed grouse	3	735	2,205
Tetraonidae, ?species	grouse, unidentified	6	c. 540	c. 3,240
15. *Colinus virginianus*	bobwhite	2	165	330
16. *Meleagris gallopavo*	wild turkey	1	5,450	5,450
17. cf. *Rallus limicola*	Virginia rail	1	85	85
18. *Porzana carolina*	sora rail	2	80	160
19. *Gallinula chloropus*	common gallinule	1	600	600
Rallidae, ?species	rail, unidentified	1	c. 83	c. 83
20. *Pluvialis dominica*	American golden plover	1	145	145
21. *Philohela minor*	American woodcock	4	155	620
22. *Capella gallinago*	common snipe	1	100	100
23. cf. *Actitis macularia*	spotted sandpiper	2	40	80
24. cf. *Tringa solitaria*	solitary sandpiper	2	60	120
25. cf. *Limosa*, ?species	godwit	3	350	1,050
Scolopacidae, ?species	sandpiper/plover	7	c. 75	c. 525
26. *Ectopistes migratorius*	passenger pigeon	30	300	9,000
27. *Coccyzus*, ?species	cuckoo	1	60	60
28. *Otus asio*	screech owl	1	160	160
29. *Bubo virginianus*	great horned owl	1	1,375	1,375

Table 4. Plant and animal remains, Entrance 2, Site 3, Clark's Cave (continued).

Scientific name	Common name	MNI	Gram live weight	Total gram live weight
AVES (continued)				
30. *Asio* cf. *flammeus* or *otus*	short-eared or long-eared owl	3	400	1,200
31. *Aegolius acadicus*	saw-whet owl	1	85	85
32. *Chordeiles minor*	common nighthawk	1	80	80
33. *Chaetura pelagica*	chimney swift	1	22	22
34. *Megaceryle alcyon*	belted kingfisher	1	140	140
35. *Colaptes auratus*	common flicker	3	135	405
36. *Dryocopus pileatus*	pileated woodpecker	2	280	560
37. cf. *Centurus carolinus*	red-bellied woodpecker	1	78	78
38. *Sphyrapicus varius*	yellow-bellied sapsucker	1	50	50
39. *Dendrocopos villosus*	hairy woodpecker	1	50	50
40. *Dendrocopos pubescens*	downy woodpecker	1	26	26
Picidae, ?species	woodpeckers, unidentified	2	c. 70	c. 140
41. *Empidonax,* ?species	flycatcher	1	c. 12	c. 12
42. *Eremophila alpestris*	horned lark	1	40	40
43. *Petrochelidon pyrrhonota*	cliff swallow	9	23	207
44. *Perisoreus canadensis*	gray jay	1	75	75
45. cf. *Cyanocitta cristata*	blue jay	1	85	85
46. *Corvus brachyrhynchos*	common crow	1	412	412
47. *Parus*, ?species	chickadee	1	10	10
48. *Parus bicolor*	tufted titmouse	1	21	21
49. *Sitta* cf. *canadensis*	red-breasted nuthatch?	1	11	11
50. *Certhia familiaris*	brown creeper	2	8	16
51. *Cistothorus* cf. *platensis*	short-billed marsh wren?	1	9	9
52. cf. *Toxostoma rufum*	brown thrasher	1	70	70
53. *Turdus migratorius*	robin	2	80	160
54. *Catharus,* ?species	thrush	2	c. 32	c. 64
55. cf. *Sialia sialis*	eastern bluebird	1	31	31
56. cf. *Anthus spinoletta*	water pipit	1	23	23
57. *Bombycilla cedrorum*	cedar waxwing	1	31	31
58. cf. *Dendroica coronata*	yellow-rumped warbler	1	13	13
59. *Seiurus*, ?species	water thrush	1	20	20
Parulidae, ?species	warblers, unidentified	2	c. 12	c. 24
60. cf. *Dolichonyx oryzivorus*	bobolink	1	34	34
61. cf. *Sturnella*, ?species	meadowlark	1	97	97
62. *Agelaius phoeniceus*	red-winged blackbird	1	60	60
63. cf. *Icterus spurius*	orchard oriole	1	21	21
64. *Piranga*, ?species	tanager	1	29	29
65. cf. *Pinicola enucleator*	pine grosbeak	1	57	57
66. *Loxia*, ?species	crossbill	1	30	30
67. *Pooecetes gramineus*	vesper sparrow	1	25	25
68. *Junco hyemalis*	dark-eyed junco	2	20	40
Fringillidae, ?species	sparrows, unidentified	2	c. 18	c. 36

Table 4. Plant and animal remains, Entrance 2, Site 3, Clark's Cave (continued).

Scientific name	Common name	MNI	Gram live weight	Total gram live weight
MAMMALIA	Mammals	4,343		204,315.0
(Identified by J.E. Guilday)				
1. *Sorex arcticus*	arctic shrew	13	8.3	107.9
2. *Sorex cinereus*	masked shrew	67	4.1	274.7
3. *Sorex dispar*	long-tailed shrew	4	5.0	20.0
4. *Sorex fumeus*	smoky shrew	10	8.0	80.0
5. *Sorex palustris*	water shrew	7	12.3	86.1
Sorex, ?species	shrews, unidentified	26	c. 7.5	c. 196.0
6. *Microsorex hoyi*	pygmy shrew	7	3.2	22.4
7. *Blarina brevicauda*	short-tailed shrew	97	19.3	1,872.1
8. *Parascalops breweri*	hairy-tailed mole	12	52.0	624.0
9. *Scalopus aquaticus*	eastern mole	1	102.0	102.0
10. *Condylura cristata*	star-nosed mole	13	56.5	734.5
11. *Myotis lucifugus* or *sodalis*	little brown bat	c. 877		
12. *Myotis keenii*	Keen's bat			
13. *Myotis leibii*	small-footed bat	c. 138	c. 7.5	c. 8,647.0
14. *Myotis grisescens*	gray bat	c. 138		
15. *Pipistrellus subflavus*	eastern pipistrelle	26	4.5	117.0
16. *Eptesicus fuscus*	big brown bat	363	17.5	6,352.5
17. *Plecotus* cf. *townsendii*	big-eared bat	9	7.5	67.5
18. *Lasiurus borealis*	red bat	3	12.0	36.0
19. cf. *Sylvilagus transitionalis*	New England cottontail	1	969.0	969.0
20. *Lepus americanus*	snowshoe hare	23	1,500.0	34,500.0
21. *Tamias striatus*	eastern chipmunk	24	97.0	2,328.0
22. *Eutamias minimus*	least chipmunk	3	42.9	128.7
23. *Marmota monax*	woodchuck	2	2,850.0	5,700.0
24. *Spermophilus tridecemlineatus*	13-lined ground squirrel	5	150.0	750.0
25. *Sciurus* cf. *carolinensis*	gray squirrel	3	520.0	1,560.0
26. *Tamiasciurus hudsonicus*	red squirrel	25	185.0	4,625.0
27. *Glaucomys volans*	southern flying squirrel	19	60.0	1,140.0
28. *Glaucomys sabrinus*	northern flying squirrel	28	107.0	2,996.0
Tamias or *Glaucomys*	squirrels, unidentified	8	c. 88.0	c. 704.0
29. *Peromyscus maniculatus*	deer mouse	c. 117	21.0	c. 2,457.0
30. *Peromyscus leucopus*	white-footed mouse	c. 104	22.0	c. 2,288.0
31. *Neotoma floridana*	eastern woodrat	51	360.0	18,360.0
32. *Clethrionomys gapperi*	red-backed vole	305	24.0	7,320.0
33. *Phenacomys intermedius*	heather vole	34	33.0	1,122.0
34. *Microtus pennsylvanicus*	meadow vole	c. 658	35.9	23,622.0
35. *Microtus chrotorrhinus*	rock vole	c. 292	35.0	10,220.0
36. *Microtus xanthognathus*	yellow-cheeked vole	511	90.0	45,990.0
37. *Microtus pinetorum*	woodland vole	170	25.6	4,352.0
38. *Ondatra zibethicus*	muskrat	6	1,050.0	6,300.0
39. *Synaptomys cooperi*	southern bog lemming	23	28.3	650.9
40. *Synaptomys borealis*	northern bog lemming	61	33.0	2,013.0

Table 4. Plant and animal remains, Entrance 2, Site 3, Clark's Cave (continued).

Scientific name	Common name	MNI	Gram live weight	Total gram live weight
MAMMALIA (continued)				
41. *Zapus hudsonius*	meadow jumping mouse	22	18.0	396.0
42. *Napaeozapus insignis*	woodland jumping mouse	15	24.0	360.0
43. *Erethizon dorsatum*	porcupine	1	*	*
44. *Canis* cf. *dirus*	dire wolf	1	*	*
45. *Ursus americanus*	black bear	1	*	*
46. *Procyon lotor*	raccoon	1	*	*
47. *Martes americana*	marten	1	661.0	661.0
48. *Mustela nivalis*	least weasel	7	41.0	287.0
49. *Mustela erminea*	ermine	4	54.0	216.0
Mustela, (frenata or *erminea)*	weasel, unidentified	1	c. 60.0	c. 60.0
50. *Mustela vison*	mink	2	620.0	1,240.0
51. *Mephitis mephitis*	striped skunk	1	1,660.0	1,660.0
52. *Cervus elaphus*	elk	1	*	*
53. cf. *Odocoileus virginianus*	white-tailed deer	1	*	*

BIOTIC DISCUSSIONS

FLORA

Plant remains, probably of Recent origin, were incidental in the deposit. Some (hackberry seeds) were probably introduced by cliff-frequenting rodents, others (hemlock needles, etc.), by wind. All eight species grow in the area today. (Floral List, Table 4).

DECAPODA—Crayfish

The few crayfish represented were probably raptor food remains. Two species, represented by claw fragments, were present. *Cambarus* cf. *bartonii* and *C.* cf. *longulus* are both present in the Cowpasture River today. The former ranges from Georgia north to New Brunswick, the latter from the Yadkin River of North Carolina to the James River drainage. Dr. Hobbs comments "The punctations on the fingers are somewhat larger than those typical of either species, but if these remains had passed through the alimentary canal of some mammal [or bird, ed.] this may have been responsible for the disproportionately greater solution of these setae-bearing depressions" (letter, 3/7/73).

INSECTA—Insects

Insect remains were scarce and fragmentary. Twenty-nine of the 32 individuals identified were beetles. Scarab beetles, hide beetles, and flesh flies are attracted to decaying organic matter like raptor roost litter. Wasps probably used the cliffs as nest sites protected from the weather. All remains appeared to be Recent.

MOLLUSCA—Snails and Clams

Approximately 4,363 gastropods were recovered, some 4,300 of which were the small freshwater snail *Spirodon carinata,* common in the river today. They may have formed a minor food item or been inadvertently introduced clinging to nesting materials collected by birds or woodrats. Nineteen species of land snails were represented by only 63 shells in this seemingly lime-rich environment. The site may have been too dry or the decaying owl pellets too acidic to attract them. All species are still present in the area and are broadly distributed in the Appalachians today.

The two species of fingernail clams (Sphaeriidae) were probably also inadvertent inclusions.

PISCES—Fish

Remains of 57 small fish, seven species, 1% of the total vertebrates, were recovered. They were uniformly small and minnow-size, although a few of the suckers reached an estimated length of 30 cm. Identifications were based upon diagnostic cranial elements, and in the case of catfish, pectoral fin spines as well. Approximately 4,000 unidentified small fish vertebrae were recovered. All identified species are present in the James River drainage today. The fish are catalogued under CM 29689.

Fish formed a minor food item and may have been taken by bankside scavenging or inadvertently introduced as stomach contents of other prey items. But at least some owls do actively fish. Dr. Claude W. Hibbard (letter, 10/15/62) reported finding, as a boy, screech owls (*Otus asio)* caught in jump traps set in shallow water that had been baited with shiny tinfoil to attract curious raccoons. The owls apparently mistook the shiny foil for fish and struck.

AMPHIBIA—Amphibians

Order Anura—Frogs and Toads

Family Bufonidae

Bufo (americanus group, *sensu* Blair)—Toad

MATERIAL: CM 29582: 141 left, 133 right ilia. MNI = 141 individuals.

Family Hylidae

Hyla cf. *crucifer*—Spring Peeper

MATERIAL: CM 29581: 20 left, 17 right ilia. MNI = 20 individuals.

Family Ranidae

Rana cf. *catesbeiana*—Bullfrog

MATERIAL: CM 29574: 5 left, 2 right ilia. MNI = 5 individuals.

Rana cf. *clamitans*—Green Frog

MATERIAL: CM 29575: 1 left, 2 right ilia. MNI = 2 individuals. CM 29576: (*R. catesbeiana* or *clamitans):* 2 left, 2 right ilia. MNI = 2 individuals.

Rana cf. *pipiens* group—Leopard Frog

MATERIAL: CM 29577: 13 left, 22 right ilia. MNI = 22 individuals.

Rana ef. *palustris*—Pickerel Frog

MATERIAL: CM 29578: 18 left, 22 right ilia. MNI = 22 individuals.

Rana cf. *sylvatica*—Wood Frog

MATERIAL: CM 29579: 41 left, 42 right ilia. MNI = 42 individuals.

Rana, species indeterminate

MATERIAL: CM 29580: 36 left, 29 right fragmentary ilia. MNI = 36 individuals.

REMARKS: A minimum of 141 toads and 151 frogs, 6% of the total vertebrates, were recovered from the site. Identifications were based primarily on characters of the ilium, although frontoparietals and sacra were also studied. The following ilial characters were used:

Rana catesbeiana: steep posterior slope of ilial prominence, non-sinuate outline of the prominenee viewed dorsally; large size.

R. clamitans: steep posterior slope of ilial prominence; sinuate outline of the prominence viewed dorsally (except in immature specimens).

R. pipiens: moderately steep angle of ilial prominence; presence of a ridge and pit; ilial prominence blade-like to moderately knob-like (may be some overlap with *R. sylvatica).*

R. palustris: gently sloping ilial prominence and well-defined ridge (Holman, 1967). Some specimens could be *R. pipiens* or *R. sylvatica.*

Hyla crucifer: The hylid ilia from Clark's Cave are referable to *Hyla* on the basis of the ventral acetabular expansion, which is wider than in *Acris* or *Pseudacris.* The angle between the shaft of the ilium and the acetabular expansion is obtuse, unlike *Acris* and *Pseudacris. Hyla crucifer* is unusual for the genus in that dorsal protuberance is almost always above the anterior half of the acetabular fossa, or completely anterior to it (Lynch, 1966). This is the case in all Clark's Cave specimens.

Considering the boreal nature of the deposit, the possibility of mink frog, *R. septentrionalis* was considered. Thirteen of the 237 *Rana* ilia had a keel on the shaft, a character noted on three Recent specimens of the mink frog from the Carnegie Museum collections. These also lacked a pit. However, all of the Clark's Cave specimens may be variants of *R. pipiens, R. palustris,* or *R. sylvatica.*

The peepers, *H. crucifer,* 20 individuals, are arboreal, small, and probably not available for predation by raptors except perhaps during spring breeding aggregation. Their occurrence at the site is incidental.

Of the remaining 131 frogs, 5 species of the genus *Rana,* only 7%, were "deep-water" frogs (river, lake, pond), bull, and green frogs. The other three species, leopard, pickerel, and wood frog, especially the latter, are more terrestrial, frequenting swampland, wet meadows, and woodland. All congregate in standing water swampland during spring breeding aggregation. All are common in the area today. The pickerel frog appears to be especially common in and around cave streams in Virginia today (Holsinger, 1964).

Birds of prey, like most carnivores, are opportunists, and these frogs were probably prey items. The relatively small number suggests that they were taken sporadically. But frogs would be available only during the warmer portion of the year, so that their relatively low numbers may be a poor reflection of their possible seasonal importance.

Almost one-half of the anurans were toads of the genus *Bufo*. Two species occur in western Virginia at the present time, *Bufo americanus*, the American toad, and *Bufo woodhousei fowleri*, Fowler's toad. The two species could not be separated on the basis of the recovered fossils and both may be represented. Although remains of the eastern spadefoot toad, *Scaphiopus holbrooki*, were recovered from the Natural Chimneys, Va. deposit, no evidence of this species was noted at Clark's Cave. Nocturnal, terrestrial and slow-moving, toads would appear to be susceptible to owl predation. Frogs and "amphibians" have been reported from owl food remains (Latham, 1950), but toads are rarely specified. Howell, 1932, and Munro, 1929, refer to toads in the stomachs of burrowing owls, *Speotyto cunicularia*, so that the skin secretions, so distasteful to mammals, apparently do not deter at least the burrowing owl. We would like to thank Harold D. Mahan, Director, Cleveland Museum of Natural History, for the bur-

Table 5. Measurements (in mm)[1] of *Bufo* (*americanus* group) Sacra.

Locality	$\bar{X}$	OR	N
Width of centrum at condyles			
Clark's Cave, Va., late Pleistocene	28.89	22.5–36.0	33
New Paris No. 4, Pa., late Pleistocene	-----	11.5–32.5	---
Southwestern Pa., Recent CM 37153, *Bufo americanus*	34.5	------	1
Length of centrum			
Clark's Cave, Va., late Pleistocene	25.34	20.0–34.5	32
New Paris No. 4, Pa., late Pleistocene	-----	11.5–31.0	---
Southwestern Pa., Recent CM 37153, *Bufo americanus*	33.0	------	1
Width of centrum, anterior end			
Clark's Cave, Va., late Pleistocene	22.0	16.0–33.0	31
New Paris No. 4, Pa.,	-----	10.0–23.5	---
Southwestern Pa., Recent CM 37153, *Bufo americanus*	28.0	------	1
Height of centrum, anterior end			
Clark's Cave, Va., late Pleistocene	14.1	9.0–17.5	33
New Paris No. 4, Pa., late Pleistocene	-----	6.0–15.0	---
Southwestern Pennsylvania, Recent CM 37153, *Bufo americanus*	15.0	-----	1

[1]Measurements by H. McGinnis.

rowing owl observations.

Measurements of *Bufo* sacra from Clark's Cave appear to fall within the range of Recent *Bufo americanus,* and are larger than those of the smaller of the two size groups from New Paris No. 4, Pa., identified as *B. a. copei.*

Order Urodela—Salamanders

A minimum of 36 salamanders, estimated by vertebra and limb bone eounts, are eatalogued under CM 29692 (see Faunal List). They were undoubtedly incidental food items. Although salamanders are common in the area, the immediate excavation site appears too well-drained and dry to attract them today.

REPTILIA—Reptiles

Order Chelonia—Turtle

A single unidentified carapace fragment (CM 29695) is the only evidence of turtle in the deposit. Because of the selection bias of the birds of prey it is not clear whether the absence of turtles from the site is a reflection of cooler environmental conditions (as at New Paris No. 4, Pa.) or immunity from predation.

Order Squamata—Lizards and Snakes

A minimum number of 13 fence lizards (CM 29584) and two broad-headed skinks (CM 29585) were based on characters of the dentary and compared directly with Recent specimens from the Carnegie Museum collections. Both species occur at the site today. The fence lizard, also reported from the Natural Chimneys, Va. deposit, reaches its northern limits today in central Pennsylvania, slightly north of the range of the broad-headed skink. Lizard remains probably post-dated the primary boreal deposit.

Snakes, ca 2,800 vertebrae (CM 29693, 29694), an estimated 20+ individuals, accounted for only 0.4% of the total vertebrate MNI. One partial vertebra was from a medium-sized crotalid. All others were from colubrids of small size. Snakes were a minor item of owl diet. Large snakes appear to have been deliberately avoided. Colubrids, especially natricines, were common in the boreal New Paris No. 4 deposit, so those at Clark's Cave may have been contemporaneous with the bulk of the late Pleistocene fauna at the site.

AVES—Birds

Bird remains from the Clark's Cave deposit totaled 3,600 pieces. Approximately 212 individuals, belonging to 68 species in 34 families, were represented. In addition, slightly over 700, or 72% of the bird-bone sample identified to order, consisted of indeterminate passerines. Avian remains from Back Creek Cave No. 2 consisted of 415 pieces, at least 17 species belonging to nine families, a minimum of 55 individuals.

The bulk of the remains resulted from the feeding activities of predatory birds. Such bone concentrations provide an index to the relative abundance and variety of a faunal assemblage, but the condition of the individual bones is often adversely affected by feeding breakage, the effects of digestive fluids, post-depositional breakage and rodent damage. A large percentage of the bones are fragmented and the diagnostic characters of the articulating ends of many are missing. In the case of the avian material from these two cave deposits, it was apparent that the larger the species (e.g. waterfowl, grouse, turkey), the greater the extent of bone fragmentation. This, combined with the difficulty of distinguishing between elements of closely related species, made many identifications only tentative. Factors that prevented species identification, or osteological characters that made certain critical determinations possible, will be discussed under the various families or species of birds below.

Order: Podicipediformes
Family: Podicipedidae—Grebes

Podilymbus podiceps (Linnaeus)—Pied-billed Grebe

MATERIAL: CM 29613. Paired quadrates: incomplete sternum, coracoids, tarsometatarsus, ulna. MNI = 2 individuals.

REMARKS: The pied-billed grebe is a common migrant and fairly common winter resident in the state, occuring on both lakes and rivers. Although all elements (except the quadrates) were incomplete, they are in all probability referable to this species.

Order: Ciconiiformes
Family: Ardeidae—Herons and Bitterns

Botaurus lentiginosus (Rackett)—American Bittern

MATERIAL: CM 29631. Incomplete left humerus. MNI = 1 individual.

REMARKS: Both ends of this humerus were missing, but the overall dimensions, location of the deltoid crest, and form/position of the impression of the *brachialis anticus* muscle compare favorably with that of the American bittern. Probably an uncommon migrant and summer resident in western Virginia.

Order: Anseriformes

Family: Anatidae—Swans, Geese, and Ducks

Anas platyrhynchos Linnaeus—Mallard, and *Anas rubripes* Brewster—Black Duck—or both

MATERIAL: CM 29614. 2 incomplete right humeri. MNI = 2 individuals.

Anas Linnaeus—Duck

MATERIAL: CM 29615. Distal ends of right tibiotarsus and coracoid. MNI = 1 individual.

cf. *Anas crecca* Linnaeus—Green-winged Teal

MATERIAL: CM 29616. Proximal end of left humerus. MNI = 1 individual.

cf. *Anas discors* Linnaeus—Blue-winged Teal

MATERIAL: CM 29617. Incomplete left humerus. MNI = 1 individual.

Lophodytes cucullatus (Linnaeus)—Hooded Merganser

MATERIAL: CM 29618. 1 proximal end, 1 distal end and shaft of right humeri. MNI = 2 individuals.

Mergus Linnaeus—Merganser

MATERIAL: CM 29678. Incomplete proximal end of left humerus. MNI = 1 individual.

Duck/Merganser spp.

MATERIAL: CM 29619. 23 non-diagnostic or fragmentary elements including coracoids, ulnae, femora, tibiotarsi, humeri.

REMARKS: All waterfowl elements were incomplete, making specific determinations especially tenuous. One indeterminate duck tibiotarsus and sternum and two humeri fragments (CM 29619) were those of small species, possibly teal, while several other pieces probably represent mergansers, some of the larger puddle ducks *(Anas)* or both. All waterfowl species represented at Clark's Cave could be found today along the Cowpasture River, primarily during migration. Because of the large size of mallards, the black duck, and mergansers *(Mergus),* it would have taken a raptor the size of a large hawk *(Buteo)* or great horned owl *(Bubo)* to capture and transport these birds to the cave entrance.

Order: Falconiformes

Family: Accipitridae—Hawks and Harriers

cf. *Accipiter striatus* Vieillot—Sharp-shinned Hawk

MATERIAL: CM 29620. Incomplete right coracoid. MNI = 1 individual.

Buteo platypterus (Vieillot)—Broad-winged Hawk

MATERIAL: CM 29621. Fragmented distal end of right tibiotarsus. MNI = 1 individual.

Hawk sp.

MATERIAL: CM 29622. Claw.

REMARKS: Hawks were poorly represented at Clark's Cave, and the paucity of their remains possibly suggests that the cave entrance was not generally used as a roosting/feeding locale. The tibiotarsus fragment, little more than the tendinal bridge and lacking the eondyles, is suggested as being that of broad-winged hawk, based on existing proportions. The claw was from a large hawk the size of a red-tailed hawk. Murray (1952:40) considers the sharp-shinned hawk a fairly common resident in the Lexington area, but an uncommon resident in southwestern Virginia. This small "bird hawk" may have been a major contributor of the numerous passerines in the deposit.

Family: Falconidae Caracaras and Falcons

Falco sparverius Linnaeus—Amerîean Kestrel

MATERIAL: CM 29623. 1 complete and 1 proximal half of left carpometacarpal; 1 proximal and 1 distal section of right tarsometatarsal. MNI = 2 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29700. Incomplete left carpometacarpus. MNI = 1 individual.

REMARKS: This small falcon, a fairly common resident or migrant in Virginia, preys upon insects, small birds and mammals. If this raptor frequented the cave entrances, it could have also been a significant contributor of small animals to the deposits.

Order: Galliformes

Family: Tetraonidae—Grouse and Ptarmigan

cf. *Canachites canadensis* (Linnaeus)—Spruce Grouse

MATERIAL: CM 29624. 14 carpometacarpals, 23 tarsometatarsi, 2 humeri, 2 ulnae, 1 coracoid, 4 tibiotarsi. MNI = 14 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29701. 10 tarsometatarsi. MNI = 6 individuals.

Bonasa umbellus (Linnaeus)—Ruffed Grouse

MATERIAL: CM 29625. Complete (or sections of) items including 1 jaw, 1 femur, 4 coracoids, 2 tibiotarsi; 24 tarsometatarsi, 14 humeri, 3 ulnae, 26 carpometacarpals. MNI = 16 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29702. 8 carpometacarpals, 10 tarsometatarsi. MNI = 6 individuals.

C. canadensis and/or *B. umbellus*—Spruce or Ruffed Grouse, or both

MATERIAL: CM 29626. A total of approximately 272 incomplete, fragmented, or non-diagnostic elements. MNI—30 to 35 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29703. A total of approximately 80 incomplete, fragmented, or non-diagnostic elements. MNI = 9 individuals.

REMARKS: Osteological differences between spruce and ruffed grouse are extremely subtle and, taking into account overlap in size between males and females within and between the species, the majority of elements of these two grouse are specifically inseparable. In general, however, certain bones of the spruce grouse appear slightly more delicate (comparing birds of the same sex) than those of the ruffed grouse. For example, the tarsometatarsus of the spruce grouse is shorter and the shaft narrower or "pinched" just posterior to the distal foramen. The pneumatic foramen in the spruee grouse humerus appears proportionally larger and more rounded (oval in *Bonasa).* The carpometacarpus of the ruffed grouse appears heavier or stouter compared with one of equal length from the spruce grouse, and the intermetacarpal process in ruffed grouse appeared better developed in the comparative specimens examined. While species identification based on other bones are more tentative it is felt that these determinations are valid and that the spruce grouse as well as the ruffed grouse is represented at both caves.

The ruffed grouse is still common in the more heavily forested regions of western Virginia. The spruce grouse, on the other hand, "a bird of the northern wilderness, of thick and tangled swamps, and of spruce forests, where the ground is deep in moss and where the delicate vines of the snowberry and twinflower clamber over moss-covered stubs and fallen, long-decayed tree trunks" (Bent, 1932: 121), was unknown in the state in historic times. Wetmore (1959) identified remains of *C. canadensis* from Natural Chimneys, Va. With the added records of this bird from the two Bath Co. caves, it is apparent that at one time this boreal grouse was definitely a part of the avifauna of western Virginia. It has also been reported from the late Pleistocene Ladds Quarry local fauna, Bartow Co., Ga. (Wetmore, 1967).

Lagopus cf. *mutus* (Montin)—Rock Ptarmigan

MATERIAL: CM 29627. Complete left humerus and tarsometatarsus. MNI = 1 individual.

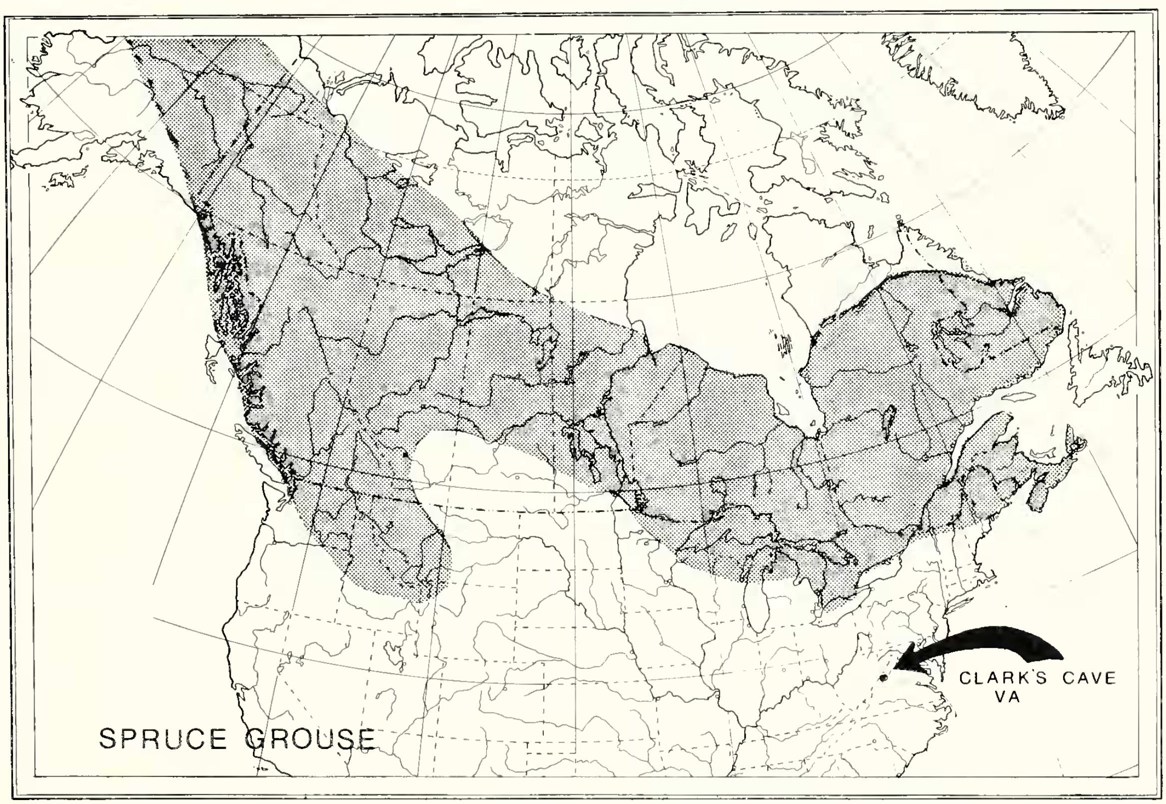

Fig. 11. Modern range of spruce grouse, *Canachites canadensis* (Linnaeus), adapted from Godfrey, 1966. Present in Clark's Cave local fauna.

MATERIAL (Back Creek Cave No. 2): CM 29704. 1 complete right and 2 left tarsometatarsi. MNI = 2 individuals.

REMARKS: The recovery of ptarmigan elements at both Bath Co. cave sites was especially significant in light of the birds' present distribution and habitat requirements. Northern Quebec and Newfoundland represent the most southern reaches of the bird's range in eastern North America, approximately 1,800 km north-northeast of Bath Co. Ptarmigan are birds of the open tundra, and their occurrence as far south as west-central Virginia is indicative of the former presence of open or semi-open expanses of tundra that must have covered the northern Appalachian Mountains during full-glacial to late Pleistocene times. The recovery of caribou (*Rangifer tarandus* L.) elements from Sullivan Co. caves in eastern Tennessee (Guilday, Hamilton, and Parmalee, 1975) also serves to substantiate the former southern extension of a tundra-like habitat and related climatic conditions to at least the central Appalachians. In a summary of their findings based on pollen data, Maxwell and Davis (1972:506) state that "When the Wisconsin ice sheet stood at its maximum position, tundra vegetation bordered the ice sheet. In the eastern United States, tundra extended at least 300 kilometers due south of the ice border at 2,700 feet (800 meters) elevation on the Allegheny Plateau. Spruce and jack (and/or red) pine forest grew at lower elevations in Virginia."

Anatomical differences among the species of *Lagopus* also are extremely subtle, and many of the fragmentary or abraded elements are difficult to distinguish from those of *Bonasa* or *Canachites*. The large, open circular pneumatie foramen of the humerus appears to be one of the more valid characters separating ptarmigan from the other two genera of grouse. The humerus and tarsometatarsus from Clark's Cave (Fig. 13) were verified as *L. mutus* by Alexander Wetmore (pers. comm. 1/29/73). The latter element is especially difficult to identify to species, however, and it is possible that the willow ptarmigan, *L. lagopus* (Linnaeus), is represented. Both species occupy a similar range in northeastern Canada, but the willow ptarmigan prefers areas of

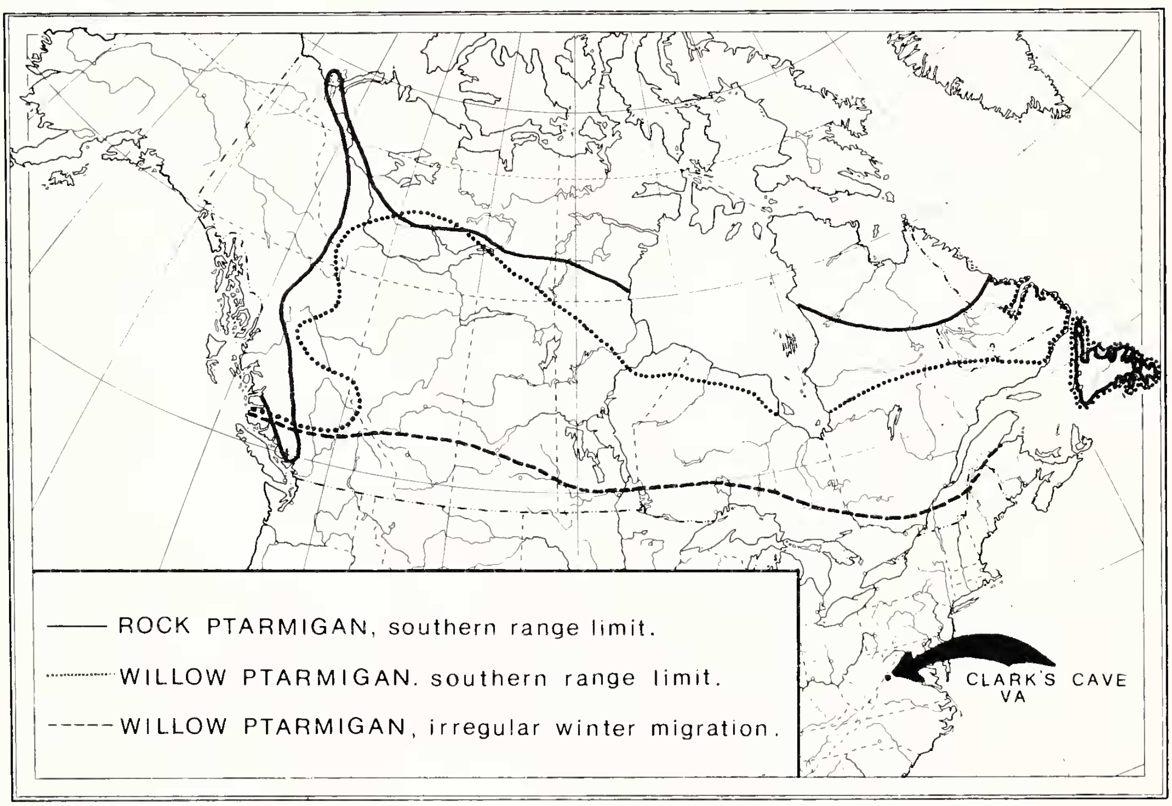

Fig. 12. Modern ranges of rock ptarmigan, *Lagopus mutus* (Montin), and willow ptarmigan, *Lagopus lagopus* (Linnaeus), adapted from Godfrey, 1966. Ptarmigan fossils present in Clark's Cave local fauna.

Fig. 13. *Lagopus* cf. *mutus* (Montin), Clark's Cave local fauna, Bath County, Virginia, CM 29627. Upper: left tarsometatarsus; lower: left humerus.

stunted and scattered trees—a habitat perhaps characteristic of the Allegheny and Shenandoah mountains in the late glacial times. Occasional winter wanderers have been recorded as far south as Maine (Kenduskeag) and northern New York (Lewis County), 680 km north of Clark's Cave (5th A.O.U. "Check-list," p.131).

However, because of certain subtle but possibly significant osteological differences noted by Storrs Olson (letter Olson/Parmalee, 10/24/75) between the cave elements and those of the rock and willow ptarmigan skeletons in the collections of the USNM, specific determinations should be considered tentative until these differences can be resolved.

cf. *Pediocetes phasianellus* (Linnaeus)—Sharp-tailed Grouse

MATERIAL: CM 29628. 2 right and 2 left carpometacarpals; sections of 3 coracoids, 1 ulna, 1 tarsometatarsus, 1 tibiotarsus, 1 humerus, 1 femur. MNI = 3 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29705. 1 nearly complete right and 1 left carpometacarpus, 4 distal ends of tibiotarsi. MNI = 4 individuals.

REMARKS: Remains of at least four sharp-tailed grouse were identified from Natural Chimneys, Va. The former presence of this grouse in west-central Virginia is also of special interest, since today its closest range proximity to the Bath County sites is northern Wisconsin and Michigan and southern Ontario (Fig. 14). Osteologically, it and the prairie chicken, *Tympanuchus cupido* (Linnaeus), are extremely similar. The synsacrum is considered by some avian osteologists to be the only specifically diagnostic element (e.g. Wetmore, 1959), so the Clark's Cave and Back Creek Cave No. 2 material lends itself only to tentative determination. Presence of this species, based upon the synsacrum, was definitely established at New Paris No. 4, Pa. during the late Pleistocene.

The overall greater length or more robust limb elements tend to differentiate bones of either *Pedioecetes* or *Tympanuchus* from those of *Bonasa* and *Canachites*. Nevertheless, another 4 tarsometatarsi and 2 carpometacarpals (CM 29629) from Clark's Cave compare closely with those of sharp-tailed grouse (*Pedioecetes* tarsometatarsi are proportionately shorter and less robust than *Tympanuchus),* yet could conceivably be from large male ruffed grouse. The sharp-tailed grouse is unknown from the state in historic times, and the prairie chicken (heath hen, *T. c. cupido)* "possibly" occurred in eastern Virginia along the Atlantic seaboard (5th A.O.U. "Check-list":136). However, the sharp-tailed grouse is certainly the "boreal" species of the two, and considering its habitation of forested regions and especially areas of low thickets and open glades or savannas, it would have been well adapted to the late Pleistocene habitat of the Appalachians.

Family: Phasianidae—Quails and Pheasants

Colinus virginianus (Linnaeus)—Bobwhite

MATERIAL: CM 29630. Complete (or sections of) items including 3 tarsometatarsi, 3 coracoids, 2 humeri, 2 carpometacarpals, sternum, radius. MNI = 2 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29706. Radius, ulna; 2 incomplete carpometacarpals, 1 tarsometatarsus, phalanx 1. MNI = 2 individuals.

REMARKS: A common bird in the open and semi-open brushy areas throughout the state, but rare in heavily forested regions.

Family: Meleagrididae—Turkeys

Meleagris gallopavo Linnaeus—Turkey

MATERIAL: CM 29632. Phalanx I; sections of scapula, humerus, tarsometatarsus, radius. MNI = 1 individual.

REMARKS: Except for the complete phalanx I, the turkey elements are fragmented and, in the case of the humerus shaft, rodent gnawed. It was reported originally to have been abundant throughout the state (Murray 1952:44). However, even the largest of raptors would have difficulty in capturing adult turkeys, and therefore the paucity of turkey remains at owl roost sites like Clark's Cave is not unexpected.

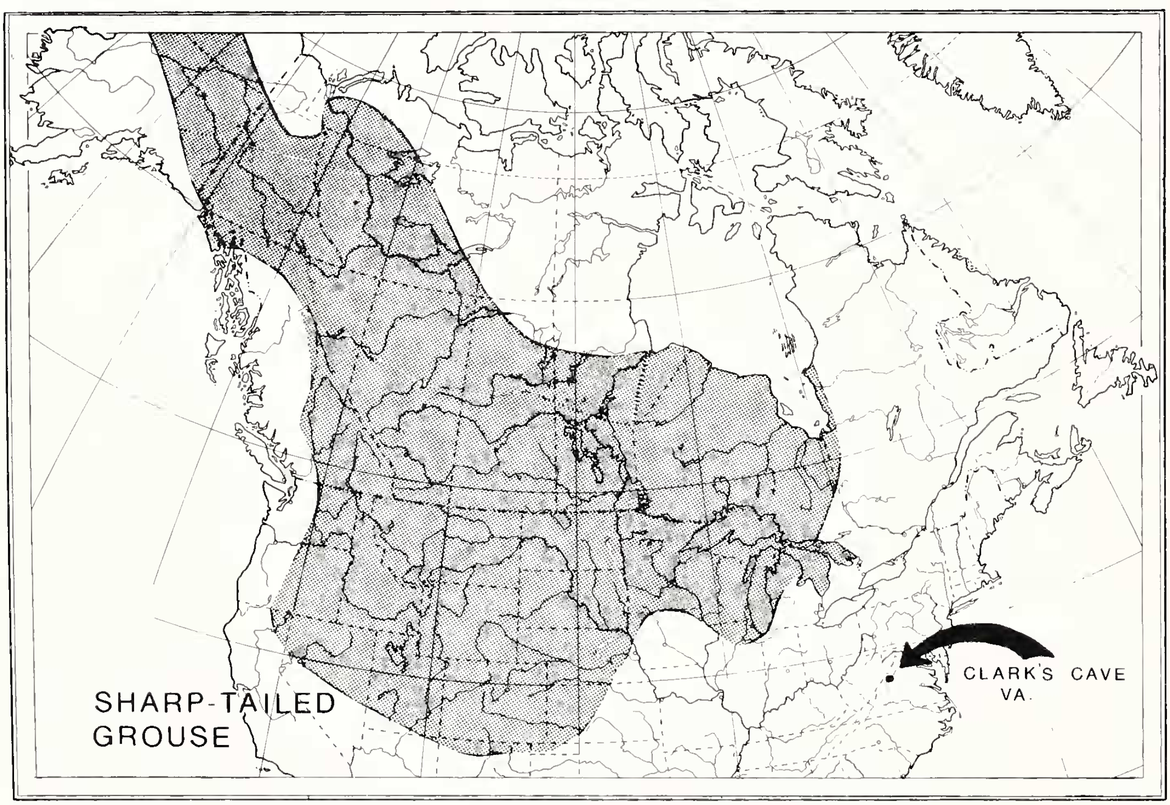

Fig. 14. Modern range of sharp-tailed grouse, *Pedioecetes phasianellus* (Linnaeus), adapted from Godfrey, 1966. Present in Clark's Cave local fauna.

Order: Gruiformes

Family: Rallidae—Rails, Gallinules, and Coots

cf. *Rallus limicola* Vieillot—Virginia Rail

MATERIAL: CM 29633. Distal third of right tibiotarsus. MNI = 1 individual.

Porzana carolina (Linnaeus)—Sora Rail

MATERIAL: CM 29634. Incomplete sections of 2 tarsometatarsi, 1 tibiotarsus, 1 coracoid, 2 humeri, 2 carpometacarpals. MNI = 2 individuals.

REMARKS: Apparently a fairly common migrant and nesting bird locally in western Virginia (Blacksburg), the Virginia rail would not be unexpected in the marshy grasslands bordering the Cowpasture River. The sora, although less numerous in the western part of the state than it is along the coastal tidewater marshes, is reportedly not uncommon locally in inland marshes and river flood plains. A fragmented right carpometacarpus (CM 29635) of what appears to be an additional species of small rail (yellow or black?) was recovered at Clark's Cave.

cf. *Gallinula chloropus* (Linnaeus)—Common Gallinule

MATERIAL: CM 29636. Distal end of lower mandible. MNI = 1 individual.

REMARKS: This section of bill is too fragmentary to permit an unquestionable determination but, on the basis of comparative specimens examined, it appears to be this species rather than eoot (*Fulica americana*) or purple gallinule (*Porphyrula martinica*). There are numerous migration and nesting records of the common gallinule in Virginia (Murray, 1952:46,47). Wet lowlands bordering the Cowpasture River could have afforded this gallinule, as well as other marsh-dwelling species like the rails and woodcock, suitable nesting habitat.

Order: Charadriiformes

Family: Charadriidae—Plovers and Turnstones

Pluvialis dominica (Muller)—American Golden Plover

MATERIAL: CM 29637. Complete left tarsometatarsus. MNI = 1 individual.

REMARKS: Murray (1952:48) states that the American golden plover is rare inland, but he lists fall occurrence of this bird at Roanoke and Blacksburg.

Family: Scolopacidae—Woodcock, Snipe, and Sandpipers

Philohela minor (Gmelin)—American Woodcock

MATERIAL: CM 29638. Complete (or sections of) items including 6 tarsometatarsi, 2 femora, 2 scapulae, 3 coracoids, 2 carpometacarpals, 2 humeri, 2 quadrates, radius, ulna. MNI = 4 individuals.

REMARKS: The American woodcock is reported to be a rare to uncommon summer resident throughout most of Virginia, but Murray (1952:49) does list young observed in Shenandoah Park, Bath, and Alleghany counties. Marshes 1.6 km south and 3 km northeast of Clark's Cave could have provided suitable habitat.

Capella gallinago (Linnaeus)—Common Snipe

MATERIAL: CM 29639. Complete left coracoid. MNI = 1 individual.

cf. *Actitis macularia* (Linnaeus)—Spotted Sandpiper

MATERIAL: CM 29640. 2 tarsometatarsi, 2 femora, 1 carpometacarpal, 3 coracoids; incomplete sections of 2 humeri, 1 tibiotarsus. MNI = 2 individuals.

?*Tringa solitaria* Wilson—Solitary Sandpiper

MATERIAL: CM 29641. 2 right distal end sections of tarsometatarsi. MNI = 2 individuals.

Indeterminate spp.—sandpipers/plovers

MATERIAL: CM 29642. Sections of sternum, 2 humeri, 2 ulnas, radius, 3 tibiotarsi, 3 tarsometatarsals, carpometacarpus, 10 coracoids. MNI = 6 or 7 individuals.

REMARKS: Elements of the numerous small species of plovers and sandpipers are often difficult to identify, especially when incomplete or abraded. Several complete, or nearly complete small sandpiper bones from Clark's Cave compared most favorably with those of the spotted and least sandpipers. Five of the indeterminate coracoids fall within the size range of the spotted/solitary/least group. In Virginia the spotted sandpiper is a common local summer resident. One was observed by C. O. Handley, Jr. (pers. comm. 10/7/74) on the bank of the Cowpasture River at Clark's Cave on August 13, 1974. All three species occur in varying numbers as transients or migrants within the state.

cf. *Limosa* Brisson—Godwit

MATERIAL: CM 29643. Sections of 3 right distal tibiotarsals, right eoracoid, proximal left humerus. MNI = 3 individuals.

REMARKS: In addition to these five fragmentary elements, three other large "shorebird" bone pieces (coracoid, 2 ulnae) from Clark's Cave fall within the godwit-willet size range. These remains, because of their fragmented or eroded condition, could not be specifically identified with certainty. Although both the marbled godwit, *Limosa fedoa* (Linnaeus), now on the increase, and the Hudsonian godwit, *L. hae-*

mastica (Linnaeus), were formerly common along the coast during migration, there are apparently no inland records. The willet, *Catoptrophorus semipalmatus* (Gmelin), a species similar osteologically and in size to the godwits, was reported from Natural Chimneys, Va. by Wetmore. However, after careful comparison with *Limosa* and *Catoptrophorus*, the Clark's Cave material, especially the tibiotarsi, appears to be one of the godwits.

Order: Columbiformes
Family: Columbidae—Pigeons and Doves

Ectopistes migratorius (Linnaeus)—Passenger Pigeon

MATERIAL: CM 29644. A total of approximately 275 elements, complete and incomplete; wing and leg bones predominate. MNI = 30 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29707. One bill and 24 wing and leg elements. MNI = 8 individuals.

REMARKS: Considering the former abundance of the passenger pigeon in eastern North America, it is not surprising to find quantities of their remains in early hawk or owl roost deposits like Clark's Cave and Back Creek Cave No. 2. Murray (1952:61) refers to several accounts relating the pigeons' former abundance in Virginia, including Bath County, and mentions a roost (in 1872) in Buckingham County that reportedly covered an area of four square miles. Remains of *E. migratorius* at Clark's Cave accounted for nearly 28% of the total number of identified bird bones (excluding indeterminate passerines). Until the last two decades of the 19th century, this pigeon appears to have been one of the major food items of raptors occupying these cave sites.

Order: Cuculiformes
Family: Cuculidae—Cuckoos and Roadrunners

Coccyzus Vieillot—Cuckoo

MATERIAL: CM 29645. Incomplete right carpometacarpus. MNI = 1 individual.

REMARKS: The yellow-billed cuckoo, *Coccyzus americanus* (Linnaeus), is reported to be considerably more common in Virginia than the black-billed cuckoo, *C. erythropthalmus* (Wilson), although both species could be expected in the vicinity of Clark's Cave. Even if the carpometacarpus had been complete, it is doubtful that it could have been identified to species.

Order: Strigiformes
Family: Strigidae—Typical Owls

cf. *Otus asio* (Linnaeus)—Screech Owl

MATERIAL: CM 29646. Section of a premaxilla and nasal process. MNI = 1 individual.

Bubo virginianus (Gmelin)—Great Horned Owl

MATERIAL: CM 29647. Incomplete section of left articular; sclerotic bone, possibly referable to this species. MNI = 1 individual.

Asio otus (Linnaeus)—Long-eared Owl,
Asio flammeus (Pontoppidan)—Short-eared Owl,
or both

MATERIAL: CM 29648. Sections of 3 tarsometatarsi, humerus, coracoid, 2 femora, 4 ulnae. MNI = 3 individuals.

Aegolius acadicus (Gmelin)— Saw-whet Owl

MATERIAL: CM 29649. Complete tarsometatarsus; seetions of radius, ulna, femur, coracoid. MNI = 1 individual.

Owl sp.

MATERIAL: CM 29650. Claw, 15 metapodials.

MATERIAL (Back Creek Cave No. 2): CM 29708. Section of sternum (screech owl? : CM 29708), distal end of tibiotarsus (*Aegolius* sp.? : CM 29720), elaw (CM 29721), and premaxilla fragment, possibly *A. acadicus* (CM 29719).

REMARKS: Both the screech owl and the great horned owl are fairly eommon locally throughout the state. Murray (1952:63-64) reports the long-eared owl as a rare resident, the short-eared owl as rather common in the coastal areas, also infrequent in suitable habitat throughout the mountains as a migrant and winter visitor, and the saw-whet owl as being a rare winter visitor in Virginia (C. O. Handley, Jr. saw one near Clark's Cave, Panther Gap, Sept. 7, 1975). Except for metapodials, the complete tarsometatarsus of a saw-whet owl, and the nearly complete tarsometatarsus of *Asio*, all other elements of these birds were fragmentary or eroded. The latter bone is probably referable to *Asio otus*, a species of owl assoeiated with dense stands or thickets of coniferous trees. Clark's Cave is presently (1974) being used as a feeding/roost site by barn owls, but no remains of this bird were encountered in the deposit.

Although the long-eared owl is capable of taking prey the size of ruffed grouse and cottontails, most of its food consists of small rodents and, to a lesser extent, small birds. Screeeh owls utilize both small birds and rodents, while the saw-whet owl feeds primarily on small rodents. The great horned owl is known to take mammals like skunks and porcupine, and birds as large as the Canada goose, turkey, and the red-tailed hawk have been recorded as prey of this owl. Data on the food habits of the great horned owl provided by Bent (1938:306-312) are indicative of the variety of prey species remains that might be expected at a roost site. It is apparent from the variation in size of the animals represented in the Clark's Cave deposit that both large and small raptorial birds contributed.

Order: Caprimulgiformes
Family: Caprimulgidae—Goatsuckers

Chordeiles minor (Forster)—Common Nighthawk

MATERIAL: CM 29651. Incomplete right humerus and right coracoid. MNI = 1 individual.

REMARKS: A common summer resident and migrant over much of the state.

Order: Apodiformes
Family: Apodidae—Swifts

Chaetura pelagica (Linnaeus)—Chimney Swift

MATERIAL: CM 29652. Complete left carpometacarpus. MNI = 1 individual.

REMARKS: A common summer resident throughout the state.

Order: Coraciiformes
Family: Alcedinidae—Kingfisher

Megaceryle alcyon (Linnaeus)—Belted Kingfisher

MATERIAL: CM 29653. Incomplete right humerus, left carpometacarpus, and left coracoid. MNI = 1 individual.

REMARKS: The belted kingfisher occurs as a permanent resident in Virginia, varying in abundance locally depending upon season and general habitat. Birds were observed by C. O. Handley, Jr. (letter Handley/Parmalee, 10/7/74) along the Cowpasture River in September, 1974. Wetmore reported it from Natural Chimneys, Va.

Order: Piciformes
Family: Picidae—Woodpeckers

Colaptes auratus (Linnaeus)—Common Flicker

MATERIAL: CM 29654. 1 complete left carpometacarpus, incomplete elements including 1 ulna, 4 carpometacarpals, 3 tarsometatarsi, femur, coracoid. MNI = 3 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29709. 3 incomplete carpometacarpals, femur, tarsometatarsus and 2 humeri (juvenile ?; also a tibiotarsus and tarsometatarsus section of a juvenile woodpecker, possibly flicker). MNI = 2 individuals.

Dryocopus pileatus (Linnaeus)—
Pileated Woodpecker

MATERIAL: CM 29655. 2 incomplete right humeri, right scapula. MNI = 2 individuals.

cf. *Centurus carolinus* (Linnaeus)—
Red-bellied Woodpecker

MATERIAL: CM 29656. 1 partial right and 1 partial left humerus. MNI = 1 individual.

? *Melanerpes erythrocephalus* (Linnaeus)—
Red-headed Woodpecker

MATERIAL (Back Creek Cave No. 2): CM 29710. Distal end of left humerus. MNI = 1 individual.

Sphyrapicus varius (Linnaeus)—
Yellow-bellied Sapsucker

MATERIAL: CM 29657. Proximal end of left humerus. MNI = 1 individual.

Dendrocopos villosus (Linnaeus)—
Hairy Woodpecker

MATERIAL: CM 29658. Proximal end of right humerus, nearly complete right tibiotarsus. MNI = 1 individual.

MATERIAL (Back Creek Cave No. 2): CM 29711. Complete left carpometacarpus and tarsometatarsus, distal end of right tarsometatarsus. MNI = 1 individual.

Dendrocopos pubescens (Linnaeus)—
Downy Woodpecker

MATERIAL: CM 29659. 1 incomplete left carpometacarpus, distal end of left tarsometatarsus. MNI = 1 individual.

Woodpecker ssp.

MATERIAL: CM 29660. Sections of femur, radius, carpometacarpus, and 2 tarsometatarsi. MNI = probably 2 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29712. Sections of 4 tarsometatarsi (1 juvenile), tibiotarsus, carpometacarpus and ulna. MNI = 3 individuals.

REMARKS: All species of woodpeckers represented in these two cave deposits are considered permanent residents in Virginia, and all may be found today in Bath County. The indeterminate woodpecker elements all appear to be within the size range of the red-bellied/red-headed/hairy woodpecker group.

Woodpeckers appear to be particularly susceptible to predation by raptorial birds, and their remains often occur in cave and rock-shelter deposits. To illustrate, approximately 400 bird bones were recovered at the Raven Rocks Site, Belmont County, Ohio (Shane and Parmalee, in press). At least 15 species were represented and nearly 12% of the bones were those of woodpeckers. Of these, at least one-third were nestlings or juveniles.

Order: Passeriformes
Family: Tyrannidae—Flycatchers

Empidonax Cabanis—Flycatcher

MATERIAL: CM 29661. Complete right humerus. MNI = 1 individual.

REMARKS: This element compares closely with the yellow-bellied flycatcher, *E. flaviventris* (Baird and

Baird), and the Acadian flycatcher, *E. virescens* (Vieillot). The former species is an uncommon migrant in Virginia, the latter a common summer resident. C. O. Handley, Jr. heard several Acadian flycatchers singing along the Cowpasture River at Clark's Cave in June and August, 1974 (letter Handley/ Parmalee, 10/7/74).

Family: Alaudidae—Larks

cf. *Eremophila alpestris* (Linnaeus)—Horned Lark

MATERIAL: CM 29662. Complete left coracoid. MNI = 1 individual.

REMARKS: Although this coracoid compares well with the horned lark, a bird of the open grasslands, identification must remain tentative. The coracoid has proved to be specifically non-diagnostic in a large number of passerine birds, especially in those groups containing numerous closely related species.

Family: Hirundinidae—Swallows

Petrochelidon pyrrhonota (Vieillot)—Cliff Swallow

MATERIAL: CM 29663. Complete (or sections of) items including 13 humeri, 4 ulnae, carpometacarpus, coracoid, and tarsometatarsus. In addition, there are 12 fragmented or abraded swallow elements (CM 29664) that are probably referable to this species. MNI = 9 individuals.

REMARKS: The cliff swallow, a local summer resident in Virginia, may still be found nesting in natural cliff sites, although nests of colonies are most often observed in barn eaves and under bridge floors and railings. Apparently one or more of the hawks or owls utilizing Clark's Cave preyed upon local nesting colonies of these swallows. It is of interest to note, however, that Bent (1942:480) states that "Predaceous birds cannot be considered as serious enemies of the cliff swallow." At least eight cliff swallows were represented in the avifauna of Natural Chimneys, Va. C. O. Handley, Jr. saw them flying near Clark's Cave in 1974.

Family: Corvidae—Jays, Magpies, and Crows

Perisoreus canadensis (Linnaeus)—Gray Jay

MATERIAL: CM 29665. Complete left ulna, proximal end of left humerus. MNI = 1 individual.

REMARKS: Although the ulna recorded here as *P. canadensis* may be subject to question because this element in general lacks good diagnostic characters, both it and the section of humerus (a good diagnostic bone) compare favorably with gray jay. The former occurrence of this bird as far south as the Shenandoah Mountains area was established when remains of it were encountered in the Natural Chimneys, Va., deposit. The gray jay is associated with boreal coniferous forests, and its former presence in Bath and Augusta counties (as an established resident and not as a casual visitor) is suggestive of a once-cooler climate and a possibly different spruce-fir forest association.

Cyanocitta cristata (Linnaeus)—Blue Jay

MATERIAL: CM 29666. Incomplete left carpometacarpus. MNI = 1 individual.

MATERIAL (Back Creek Cave No. 2): CM 29713. Proximal half of right humerus, incomplete right carpometacarpus and femur. MNI = 1 individual.

Corvus brachyrhynchos Brehm—Common Crow

MATERIAL: CM 29667. Fragmentary distal end of left humerus, proximal end of right tibiotarsus, right scapula. MNI = 1 individual.

REMARKS: Both the blue jay and common crow occur throughout Virginia as permanent residents and may be seen occasionally today in the vicinity of Clark's Cave.

Family: Paridae—Titmice

Parus Linnaeus—Chickadee

MATERIAL: CM 29668. Proximal half of right humerus, fragment of proximal end of left humerus. MNI = 1 individual.

Parus bicolor Linnaeus—Tufted Titmouse

MATERIAL: CM 29669. Proximal end of left humerus. MNI = 1 individual.

REMARKS: Both the Carolina chickadee, *Parus carolinensis* Audubon, and the black-capped chickadee, *Parus atricapillus* Linnaeus, can be expected in the vicinity of Clark's Cave. Chickadees and the tufted titmouse are fairly-common to common statewide.

Family: Sittidae—Nuthatches

cf. *Sitta canadensis* Linnaeus—
Red-breasted Nuthatch

MATERIAL: CM 29670. Complete right humerus. MNI = 1 individual.

REMARKS: This nuthatch and the white-breasted nuthatch, *Sitta carolinensis* Latham, both occur in western Virginia, varying in abundance locally from rare to common.

Family: Certhiidae—Creepers

Certhia familiaris Linnaeus—Brown Creeper

MATERIAL: CM 29671. 2 complete left tarsometatarsi. MNI = 2 individuals.

REMARKS: Murray (1952:76) reeords the brown

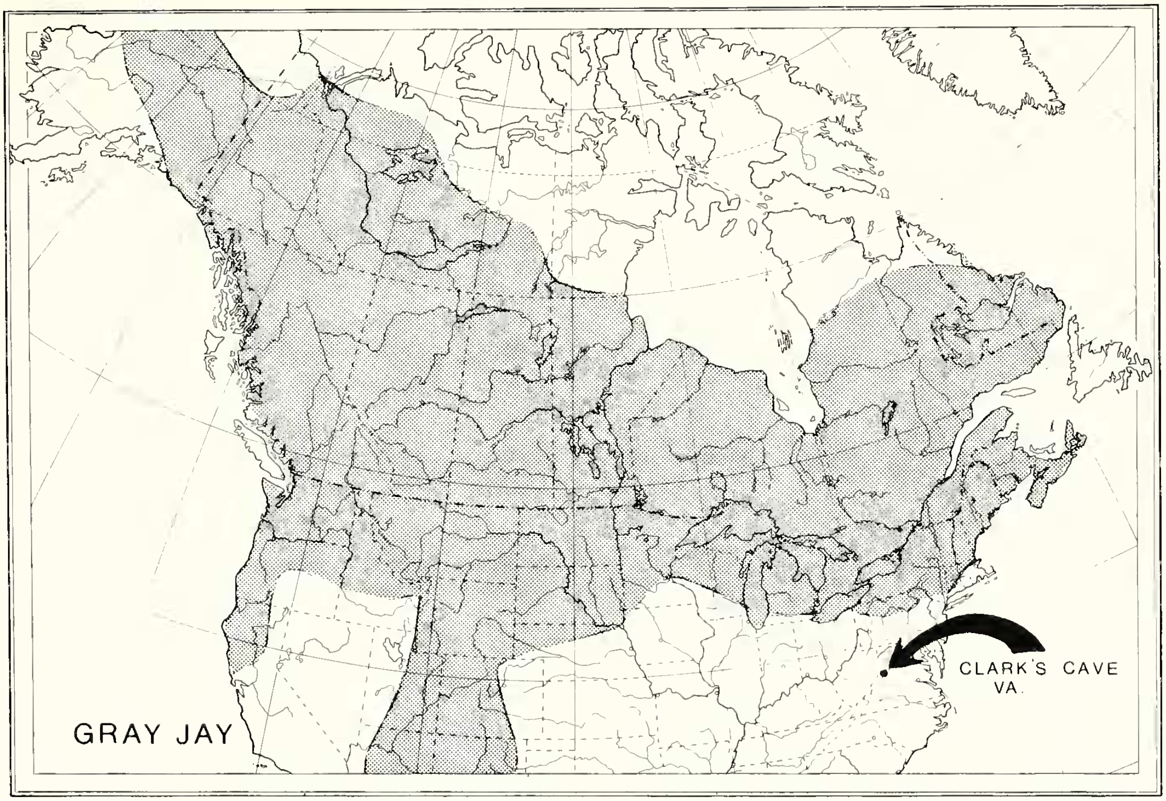

Fig. 15. Modern range of gray jay, *Perisoreus canadensis* (Linnaeus), adapted from Godfrey, 1966. Present in Clark's Cave local fauna.

creeper as a generally common winter resident and migrant in Virginia. It is also a local summer resident in the mountains. C. O. Handley, Jr. observed several nests at Mountain Lake, Giles County.

Family: Troglodytidae—Wrens

? *Cistothorus platensis* (Latham)—Short-billed Marsh Wren

MATERIAL: CM 29672. Right humerus, lacking a portion of the proximal end. MNI = 1 individual.

REMARKS: Although this humerus section compares favorably with *C. platensis*, identification can only be tentative because of its incompleteness. During spring and fall migrations this bird is a rare transient, as is the longbilled marsh wren, *Telmatodytes palustris* (Wilson), in the western and other inland regions of the state.

Family: Mimidae—Mockingbirds and Thrashers

cf. *Toxostoma rufum* (Linnaeus)—Brown Thrasher

MATERIAL: CM 29673. Proximal half of left humerus; incomplete right coracoid, possibly referable to *T. rufum*. MNI = 1 individual.

REMARKS: A common to abundant bird throughout the state.

Family: Turdidae—Thrushes, Solitaires, and Bluebirds

Turdus migratorius Linnaeus—Robin

MATERIAL: CM 29674. Complete right and left carpometacarpus, right ulna, radius and tarsometatarsus; incomplete sternum, proximal left humerus, right carpometacarpus. In addition, a complete left femur and the distal halves of a right tibiotarsus, tarsometatarsus, and humerus are also probably robin. MNI = 2 individuals.

Hylocichla Baird—Thrush

MATERIAL: CM 29675. Nearly complete right and left humeri. MNI = 2 individuals.

cf. *Sialia sialis* (Linnaeus)—Eastern Bluebird

MATERIAL: CM 29676. Incomplete proximal half of left humerus. MNI = 1 individual.

REMARKS: The robin is an abundant summer resident and migrant, and locally common winter resident in the state. The two humeri determined as *Hylocichla* fall within the size range of the veery/

hermit/gray-cheeked/Swainson's thrush group, all of which may be found in the vicinity of Clark's Cave at one season or the other. The eastern bluebird is a permanent resident in Virginia, primarily inhabiting the semi-open brush and grassland areas.

Family: Montacillidae—Wagtails and Pipits

? *Anthus spinoletta* (Linnaeus)—Water Pipit

MATERIAL: CM 29717. Incomplete right coracoid. MNI = 1 individual.

REMARKS: The distal or head portion of this element compares favorably with the water pipit. The overall head shape and extremely deep groove between the glenoid facet and the bicipital attachment (external view) appear diagnostic. However, determination is tentative because of the fragmentary condition of the coracoid. Water pipits are considered to be irregular migrants and winter visitors in most of Virginia (Murray, 1952:84).

Family: Bombycillidae—Waxwings

Bombycilla cedrorum Vieillot—Cedar Waxwing

MATERIAL: CM 29677. Complete right humerus. MNI = 1 individual.

REMARKS: A permanent resident, but erratic in occurrence in western Virginia.

Family: Parulidae—Wood Warblers

cf. *Dendroica coronata* (Linnaeus)—
Yellow-rumped Warbler

MATERIAL: CM 29679. Nearly complete right humerus. MNI = 1 individual.

? *Seiurus* Swainson—Waterthrush

MATERIAL: CM 29680. Nearly complete right humerus. MNI = 1 individual.

Warbler ssp.

MATERIAL: CM 29680. Complete (or sections of) items including 2 humeri, 2 carpometacarpals, 2 tibiotarsi, 2 ulnae, coracoid. MNI = 2 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29722. Nearly complete left humerus possibly referable to golden-winged warbler, *Vermivora chrysoptera* (Linnaeus). MNI = 1 individual.

REMARKS: Murray (1952:92) records the myrtle warbler (yellow-rumped warbler) as an "abundant transient everywhere; uncommon to abundant winter visitor as far west as Lexington; occasional in winter at Blacksburg." In addition to these few elements identified as warbler, many of the fragmentary or abraded bones recorded as Indeterminate Passerines are probably from species within this Family.

Family: Icteridae—
Meadowlarks, Blackbirds, and Orioles

cf. *Dolichonyx oryzivorus* (Linnaeus)—Bobolink

MATERIAL: CM 29681. Proximal end of right humerus. MNI = 1 individual.

cf. *Sturnella* Vieillot—Meadowlark

MATERIAL: CM 29682. Distal end of left humerus. MNI = 1 individual.

Agelaius phoeniceus (Linnaeus)—
Redwinged Blackbird

MATERIAL: CM 29683. Complete left humerus, right ulna and carpometacarpus. MNI = 1 individual.

cf. *Icterus spurius* (Linnaeus)—Orchard Oriole

MATERIAL: CM 29684. Complete right humerus. MNI = 1 individual.

REMARKS: The four icterids identified from Clark's Cave occur as permanent residents, migrants, or nesting birds in the western part of the state. Identifications based on incomplete elements or those lacking good diagnostic characters (e.g., the ulna) are recorded as tentative. However, after comparison of elements with these species and those of closely related blackbirds (e.g., Baltimore oriole and orchard oriole), it is felt that the determinations are valid.

Family: Thraupidae—Tanagers

Piranga Vieillot—Tanager

MATERIAL: CM 29685. Premaxilla. MNI = 1 individual.

REMARKS: The scarlet tanager, *Piranga olivacea* (Gmelin), is widespread and an abundant summer resident. The summer tanager, *Piranga rubra* (Linnaeus), is an uncommon and local resident in western Virginia. On the basis of this incomplete mandible section from Clark's Cave, it was not possible to identify the species.

Family: Fringillidae—
Grosbeaks, Finches, Sparrows, and Buntings

cf. *Pinicola enucleator* (Linnaeus)—Pine Grosbeak

MATERIAL: CM 29686. Anterior section of lower mandible. MNI = 1 individual.

MATERIAL (Back Creek Cave No. 2): CM 29714. Anterior section of lower mandible. MNI = 1 individual.

REMARKS: Although similar in size and general structure to the mandibles of cardinal, rose-breasted grosbeak, and evening grosbeak, these two cave specimens compare most closely with *P. enucleator*, based on the wider, more U-shaped inner angle of the symphysis and the distance of the splenial depression from the tip. Murray (1952:105) records one specimen collected in Shenandoah Park and one observed at Richmond. If the determination of these bill sections is correct, the former occurrence of this grosbeak in western Virginia represents local winter stragglers or perhaps reflects the cooler climate and spruce forests of the late Pleistocene—a habitat type now occupied by this bird.

Loxia Linnaeus—Crossbill

MATERIAL: CM 29718. Section of premaxilla. MNI = 1 individual.

MATERIAL (Back Creek Cave No. 2): CM 29723. Complete right humerus; distal end of a right humerus, probably referable to *Loxia*. MNI = 2 individuals.

REMARKS: The red crossbill, *Loxia curvirostra* Linnaeus, is considered an erratic visitor at all seasons in the Virginia mountains, and the white-winged crossbill, *Loxia leucoptera* Gmelin, an infrequent winter visitor (Murray, 1952:106).

Indeterminate sparrow ssp.

MATERIAL: CM 29687. 2 incomplete carpometacarpals, 2 humeri, coracoid.

REMARKS: An additional right humerus, tentatively determined as vesper sparrow, *Pooecetes gramineus* (Gmelin), was the only complete diagnostic element recovered of this group of fringillids, which are especially difficult to identify osteologically. The vesper sparrow is listed as a summer resident from Richmond west (Murray, 1952:109).

Junco cf. *hyemalis* (Linnaeus)—Dark-eyed Junco

MATERIAL: CM 29688. 3 complete humeri, premaxilla. MNI =2 individuals.

MATERIAL (Back Creek Cave No. 2): CM 29715. Complete left humerus. MNI = 1 individual.

REMARKS: Juncos are common winter residents throughout the state, and permanent residents in the mountains above 758 m.

MAMMALIA—Mammals

Order: Insectivora—Insectivores
Family: Soricidae—Shrews

Genus *Sorex* Linnaeus—Long-tailed shrews
Sorex arcticus Kerr—Arctic shrew

MATERIAL: CM 24540: 1 partial skull. CM 24581: 13 left, 12 right mandibles. MNI = 13 individuals.

Sorex cinereus Kerr—Masked shrew

MATERIAL: CM 24580. 67 left, 61 right mandibles. MNI = 67 individuals.

Sorex dispar Batchelder—Big-tailed or rock shrew

MATERIAL: CM 24583. 2 left, 4 right mandibles. MNI = 4 individuals.

Sorex fumeus Miller—Smoky shrew

MATERIAL: CM 24582. 9 left, 10 right mandibles. MNI = 10 individuals.

Sorex palustris Richardson—Water shrew

MATERIAL: CM 24587. 3 left, 7 right mandibles. MNI = 7 individuals.

Sorex, ?species

MATERIAL: CM 24584: 17 left, 12 right fragmentary large mandibles (*S. fumeus*/*S. arcticus*/*S. palustris*); 9 left, 10 right fragmentary small mandibles (*S. cinereus*/*S. dispar*). CM 24585: unidentified skull fragments. MNI = 26 individuals.

REMARKS: All five species of *Sorex* from the deposit inhabit at least some portion of the Appalachian Mountain chain. *Sorex arcticus*, the second commonest soricid from the Clark's Cave deposit, occurs only as far south as New Brunswick, 1,440 km northeast of Clark's Cave. It ranges across the continent, from eastern Quebec to Alaska, in boreal habitats ranging from coniferous forest to tundra. Banfield, 1974, suggests that it is typical of subclimax or transitional vegetation stages, and that while it is frequently taken in bogs and marshes, it favors a habitat slightly drier than that of other species of shrews. The water shrew, *S. palustris*, still occurs in the Appalachian Mountains south, at increasingly greater elevations, into the Great Smokies, approximately 240 km southwest of Clark's Cave (Linzey & Linzey, 1971). It has been taken in Randolph County, W. Va., and in all probability does occur in suitable mountain streamside habitats above 760 m in western Virginia (Handley & Patton, 1947). It is no longer present in the Clark's Cave area, but has recently been trapped within 15 km of the cave at a higher altitude (Pagels and Tate, 1975). Despite the riverside location of the site, *S. palustris* remains were not common (Table 6). Only *S. dispar* remains were fewer in number, reflecting the specialized habitats of these two shrews.

The peculiar habitat of the big-tailed shrew, *S. dispar*, confined to and generally deep into rocky talus, contributes to its apparent rarity. Handley (1956b) trapped it near the crest of Big Mountain at 1,200 m elevation, Giles County, Va., southwest of Clark's Cave. It has subsequently been found to be fairly common in four areas near Mountain Lake, Giles County, and also has been taken on Whitetop and Clinch Mountains. It may be expected in cool, moist, boulder and talus fields, above 600 m in the mountains (Handley & Patton, 1947). It occurs in the Clark's Cave talus today and was trapped there in 1974 by C. O. Handley, Jr. and associates. *S. dispar* occurs throughout the Appalachian chain, from Maine to Tennessee and North Carolina (Hall & Kelson, 1959). A smaller species, *S. gaspensis,* occurs in the Gaspe Peninsula of eastern Quebec, 240 km north of the range of *S. dispar.* If *S. gaspensis* is a subspecies of *S. dispar,* as some have suggested (Jackson, 1928; Banfield, 1974) this suggests that, in the northern limits of its range, *S. dispar* is not as closely confined to a talus habitat, but finds the microhabitat it requires in surface forest litter rather than in the labyrinthine cold air sinks of rock talus refuges of the South. Goodwin states (Jackson, 1928:91) that the habits of *S. gaspensis* appear to be similar to those of *S. palustris.* Although not directly compared with *S. gaspensis,* the Clark's Cave specimens agree in size with those of *S. dispar* (Table 7). *S. dispar* may therefore have been more broadly distributed during past boreal phases. This is suggested by its presence at New Paris No. 4, Pa. (4 individuals), in a region of well-drained rolling hills not physiographically suited for *S. dispar* today. The modern range of *S. dispar* suggests that, at least during Wisconsinan times, it was confined to the Appalachian region and was unable to eross or circumvent the St. Lawrence/Great Lakes water barrier into east-central Canada following glacial retreat.

The masked shrew, *S. cinereus,* the most widely distributed North American insectivore today, found in most of northern North America from Alaska to Labrador south, and in the mountains to New Mexico and North Carolina, was by far the commonest long-tailed shrew recovered from the deposit. It is possible that some of the remains may be those of the southern Bachman's shrew, *S. longirostris.* Identification was based solely on lower jaws, because of the fragmentary condition of the remains. Except for a smaller average size, lower jaws of these two species cannot be differentiated. *S. longirostris* is basically a shrew of the southern lowlands, although it has been taken in western Virginia (Handley & Patton, 1947). The Clark's Cave collection was referred to *S. cinereus* because of its larger size—somewhat larger than modern *S. cinereus* from the central Appalachians (Table 7)—and the boreal aspect of the accompanying fauna. *Sorex cinereus* was also the commonest long-tailed shrew at New Paris No. 4, Pa., a site of similar age, where the possible presence of *S. longirostris* did not arise.

The smoky shrew, *S. fumeus,* the commonest *Sorex* in the mountains of western Virginia today, and the commonest long-tailed shrew in the central and southern Appalachians (Smith *et al.,* 1974; Linzey & Linzey, 1971; Handley & Patton 1947), was not common in the deposit. Seven *S. cinereus* were recovered for every *S. fumeus,* and its remains were somewhat less common than those of the arctic shrew (Table 6). *S. fumeus* is common in the deciduous and deciduous/coniferous forests of southeastern Canada and New England. It occurs south in the Appalachian Mountains and flanking plateau areas to northern Georgia (Hall & Kelson, 1959). *S fumeus* appears to be more dependent on mature forest cover than the two commonest long-tailed shrews from the deposit, *S. cinereus* and *S. arcticus.* Its relative scarcity in mid-Appalachian late Pleistocene deposits suggests more open woodlands in comparison to the dense forest cover that now prevails. Four specimens of *S. fumeus* were trapped by C. O. Handley, Jr. and associates in the Clark's Cave talus in 1974.

Microsorex hoyi (Baird)—Pygmy shrew

MATERIAL: CM 24579. 7 left, 4 right mandibles. MNI = 7 individuals.

REMARKS: The rarest of the Appalachian long-tailed shrews today, the pygmy shrew appears to have been not as rare in late Pleistocene periglacial sites from eastern North America. It accounted for 6.5% of the long-tailed shrews from Clark's Cave (Table 6), 9.7% from Natural Chimneys, Va., 11.8% from Robinson Cave, Tenn., and 19% from New Paris No. 4, Pa. The latest review (Long, 1972a) lists only 31 modern specimens, from eastern North America, of the races *thompsoni* and *winnemana.* By way of contrast, at least 46 individuals have been recorded in that area from late Pleistocene cave sites: Bootlegger Sink, Pa. (2), New Paris No. 4, Pa. (11), Natural Chimneys, Va. (7), Clark's Cave, Va. (7), Meyer Cave, Ill. (1), Welsh Cave, Ky. (1), and Robinson Cave, Tenn. (17).

Microsorex hoyi exhibits a clear Bergmann's Response. Size increases with latitude. The largest representatives are from northern Canada and Alaska. The smallest races, *montanus,* in the Rocky Mountains, and *winnemana* in the central and southern Appalachian region, mark the southern limits of its Recent range. Surprisingly, measurements of fossil specimens from boreal Wisconsinan faunas in the East agree with those of the Recent *M. h. thompsoni* still in the area. Unlike other insectivores from these deposits which have larger northern races today, such as *Blarina brevicauda,* measurements show no trend toward larger size in *Microsorex.*

The eastern races of this shrew, *M. h. thompsoni* and *M. h. winnemana,* were originally described as separate species (Baird, 1857; Preble, 1910). Jackson, 1928, recognized only *M. hoyi,* with *thompsoni* and *winnemana* as subspecies. Long, 1972a, regarded *thompsoni* and *winnemana* as closely related to each other and distinct from *M. hoyi.* He grouped these two eastern forms under the species *M. thompsoni,* with *winnemana* as a subspecies. All of the characters differentiating *M. thompsoni* from *M. hoyi* are variable throughout the range of *M. hoyi.* Long, 1972a, and 1974, states that the elevation of *thompsoni* (includes *winnemana)* to species level is tentative and that, "this view needs further study in critical areas."

The apparent small size of these late Wisconsinan fossils suggests that *M. thompsoni* may indeed be a valid species, and that the larger northwestern *M. hoyi* may have spread into eastern Canada from the west during postglacial times. Except for the Gaspé Peninsula, where it is replaced by *M. hoyi,* the northern limit of *M. thompsoni* appears to be defined by the Great Lakes-St. Lawrence waterway, which may have acted as a barrier to its northward spread in postglacial times. Unfortunately, fossil specimens are invariably lower jaws or skull fragments. Taxonomic reviews of living species are based primarily on external characters and complete crania, so that comparison is difficult.

The pygmy shrew, despite its rarity, occurs throughout the Canadian/Hudsonian boreal forest from Alaska to Labrador, and south along the Appalachians in deciduous hardwood forests to the Great Smokies (Long, 1974). Although always found in a forested context and usually fairly close to boreal mesic habitats it may be trapped in such a variety of situations from swamp to dry open country that its presence at the site furnishes no specific ecological clues (Long, 1972b). There are only two published Recent records from the state of Virginia, both in the Piedmont, well east of the Appalachians proper: one in Fairfax Co., Va., and one at Altavista, Campbell County, 110 km southeast of Clark's Cave, both in deciduous forest (Handley & Patton, 1947). As an example of their modern rarity, Long, 1972a, was able to document only seven specimens south of Maryland. C. O. Handley, Jr., USNM, (pers. comm.) has subsequently acquired three more Virginia specimens.

Blarina brevicauda (Say)—Short-tailed Shrew

MATERIAL: CM 24541: 19 partial skulls, 3 maxillae; 26 left, 22 right mandibles. CM 24578: 67 left, 75 right mandibles; skull fragments. MNI = 97 individuals.

REMARKS: The short-tailed shrew, the commonest one in Virginia today, was also the commonest insectivore from the Clark's Cave deposit. It accounted for 42% of the seven species of shrews recovered from the cave, (42% from Natural Chimneys, Va., and 38.9% from New Paris No. 4, Pa.).

From a paleoenvironmental point of view, osteological remains of this shrew can furnish important clues. Short-tailed shrews vary markedly in size throughout their modern geographic range. Average size increases with latitude. The largest races, *B. b. brevicauda* and *B. b. manitobensis,* are from Minnesota and Manitoba. A smaller race, *B. b. kirtlandi,* occurs in the mid-Appalachians today. A much smaller species, *Blarina carolinensis,* occurs in the southern lowlands of eastern North America. A subspecies, *B. b. churchi,* larger than the mid-Appalachian *B. b. kirtlandi,* is found on the mountain summits of the southern Appalachians—apparently adapted to a cooler environment, a reflection of the same physiological forces that shaped the over-all increase in size with increasing latitude.

The short-tailed shrews from the Clark's Cave deposit were markedly larger than present day mid-

Table 6. Frequencies (%) of species of *Sorex* and *Microsorex* from three late Pleistocene Appalachian cave deposits.[1]

Species	Clark's Cave, Va.	Natural Chimneys, Va.	New Paris No. 4, Pa.
Sorex arcticus	12.0 (13)	8.3 (6)	10.3 (6)
Sorex cinereus	62.0 (67)	62.5 (45)	60.3 (35)
Sorex dispar	3.7 (4)	———	6.8 (4)
Sorex fumeus	9.3 (10)	13.9 (10)	1.7 (1)
Sorex palustris	6.5 (7)	5.5 (4)	1.7 (1)
Microsorex hoyi	6.5 (7)	9.7 (7)	19.0 (11)

[1]( ) = MNI.

Table 7. Measurements (in mm) of various species of *Sorex*.

Locality and age	$\bar{X}$	OR	SD	CV	N
	Total mandible length, condyle to anterior point of dentary				
Sorex arcticus					
Clark's Cave, Va., late Pleistocene	9.3	9.1–9.5	——	——	9
New Paris No. 4, Pa.,[1] late Pleistocene	8.9	8.7–9.3	——	——	5
S. cinereus					
Pennsylvania, modern[1]	7.28	7.1–7.7	.10	1.37	22
Clark's Cave, Va., late Pleistocene	7.57	7.3–8.0	.21	2.77	18
New Paris No. 4, Pa.,[1] late Pleistocene	7.6	7.2–7.8	.27	3.55	17
S. dispar					
Clark's Cave, Va., late Pleistocene	8.4	8.3–8.4	——	——	3
New Paris No. 4, Pa.,[1] late Pleistocene	8.2	——	——	——	2
S. fumeus					
Clark's Cave, Va., late Pleistocene	9.36	8.9–9.8	——	——	6
S. palustris					
Clark's Cave, Va., late Pleistocene	10.08	——	——	——	1
New Paris No. 4, Pa.,[1] late Pleistocene	9.5	——	——	——	1
	p4 – m3, antero-posterior crown length[2]				
S. arcticus					
Clark's Cave, Va., late Pleistocene	4.64	4.56–4.76	——	——	7
New Paris No. 4, Pa.,[1] late Pleistocene	4.4	4.2–4.5	——	——	6
S. cinereus					
Pennsylvania, modern[1]	3.69	3.6–3.9	.07	1.89	20
Clark's Cave, Va., late Pleistocene	3.98	3.6–4.4	.13	3.40	35
New Paris No. 4, Pa.,[1] late Pleistocene	3.9	3.7–4.3	.16	4.09	29
S. dispar					
Clark's Cave, Va., late Pleistocene	4.36	——	——	——	1
New Paris No. 4, Pa.,[1] late Pleistocene	4.3	——	——	——	1
S. fumeus					
Clark's Cave, Va., late Pleistocene	4.85	——	——	——	1
New Paris No. 4, Pa.,[1] late Pleistocene	4.7	——	——	——	1
S. palustris					
Clark's Cave, Va., late Pleistocene	5.04	4.9–5.2	——	——	3
New Paris No. 4, Pa.,[1] late Pleistocene	5.2	——	——	——	1

[1]Data from Guilday *et al.*, 1964.
[2]Defined as C_1 - M_3 in Guilday *et al.*, 1964 (See Repenning, 1967 for correct terminology).

Table 8. Measurements (in mm)[1] of *Microsorex*.

Taxon and locality	$\bar{X}$	OR	N
	Palatal length		
Recent:			
M. thompsoni[1]	5.60	5.30–5.84	5
M. cf. *thompsoni*, New Paris No. 3, Pa.	5.24		1
M. t. winnemana[1]	5.25		1
M. h. hoyi[1]	5.67	5.21–6.50	24
M. h. alnorum[1]	5.60	5.54–5.66	6
M. h. eximius[1]	5.86	5.70–5.98	3
M. h. washingtoni[1]	5.56		1
M. h. montanus[1]	5.4	5.26–5.54	3
Late Pleistocene:			
New Paris No. 4, Pa.	5.20	5.1–5.3	4
Welsh Cave, Ky.	5.20		1
Robinson Cave, Tenn.	5.10	4.80–5.30	3
	Maxillary breadth		
Recent:			
M. h. montanus[1]	3.9	3.9–4.0	10
M. cf. *thompsoni*, New Paris No. 3, Pa.	4.17		1
Late Pleistocene:			
New Paris No. 4, Pa.	4.15	4.0–4.3	4
Bootlegger Sink, Pa.	4.1		1
Welsh Cave, Ky.	4.1		1
	P4 – M3		
Recent:			
M. cf. *thompsoni*, New Paris No. 3, Pa.	3.39		1
Late Pleistocene:			
New Paris No. 4, Pa.	3.45	3.4–3.5	4
Robinson Cave, Tenn.	3.5	3.2–3.8	3
	Total length of mandible with il		
Recent:			
M. cf. *thompsoni*, New Paris No. 3, Pa.	8.15		1
Late Pleistocene:			
New Paris No. 4, Pa.	7.97	7.6–8.4	9
Clark's Cave, Va.	8.12	8.05–8.24	3
	Total length of dentary		
Recent:			
M. cf. *thompsoni*, New Paris No. 3, Pa.	6.6		1
Late Pleistocene:			
New Paris No. 4, Pa.	6.5	6.4–6.6	10
Bootlegger Sink, Pa.	6.3		1
Clark's Cave, Va.	6.5	6.3–6.8	7
Robinson Cave, Tenn.	6.5	5.9–7.0	7

[1]Measurements from Long, 1972a.

Table 8. Measurements (in mm)[1] of *Microsorex* (continued).

Taxon and locality	$\bar{X}$	OR	N
	Height, ascending ramus		
Recent:			
M. cf. *thompsoni.*			
New Paris No. 3, Pa.	3.0		1
Late Pleistocene:			
New Paris No. 4, Pa.	2.94	2.9–3.0	9
Bootlegger Sink, Pa.	3.0		1
Clark's Cave, Va.	2.99	2.91–3.10	7
Welsh Cave, Ky.	2.9		1
Robinson Cave, Tenn.	3.2	2.9–3.5	20
	p4 – m3		
Recent:			
M. cf. *thompsoni,*			
New Paris No. 3, Pa.	3.39		1
Late Pleistocene:			
Bootlegger Sink, Pa.	3.49		1
Clark's Cave, Va.	3.51	3.39–3.69	5
Welsh Cave, Ky.	3.6		1
	m1 – m3		
Recent:			
M. cf. *thompsoni,*			
New Paris No. 3, Pa.	2.91		1
Late Pleistocene:			
New Paris No. 4, Pa.	2.86	2.8–3.1	8
Bootlegger Sink, Pa.	2.91		1
Clark's Cave, Va.	2.97	2.8–3.2	8
Welsh Cave, Ky.	2.8		1
Robinson Cave, Tenn.	2.9	2.8–3.1	12

[1]Measurements from Long, 1972a.

Appalachian specimens, in keeping with the boreal aspect of the deposit. Four of the five cranial measurements taken average larger than those of *B. b. brevicauda* from Minnesota (Table 9). Maxillary breadth of 15 Clark's Cave skulls average only 0.14 mm smaller than the type and allotype of *B. b. manitobensis* (Anderson, 1947:23), the largest modern subspecies. Three specimens (of 15) exceeded this. The total length of the lower jaw averaged 8.6% larger, and the length of the lower toothrow (p4-m3) 7.6% larger than modern *B. b. kirtlandi.* The Clark's Cave fossil *Blarina* are comparable in size to the largest living subspecies and to the larger of the two size groups from New Paris No. 4, Pa.

The Clark's Cave sample, in addition to being composed of specimens much larger than those now in the area, appears to be homogeneous, i.e., not racially mixed. Total variation of the length of the lower jaw amounted to only 11% (% increase of largest to smallest), with a low coefficient of variation of 3.00, comparable to that of a Recent Pennsylvania sample of *B. b. kirtlandi* (Guilday *et al.*, 1964:151). In contrast, in the New Paris No. 4, Pa., *Blarina* sample, composed of a mixture of large late Pleistocene and smaller Recent specimens, total variation of that measurement rose to 20%, with a coefficient of variation of 5.74. At Meyer Cave, Ill., where the *Blarina* were markedly heterogenous, a mixture of large *B. b. brevicauda* and smaller *B. b.* cf. *kirtlandi,* total variation was 25%, over twice that shown by the Clark's Cave sample.

This is one of the few species in the deposit yield-

Table 9. Measurements (in mm) of *Blarina brevicauda*, various localities.

Locality	$\bar{X}$	OR	SD	CV	N
		Maxillary breadth			
Recent:					
Minnesota[1]	8.4	8.0–9.2	0.35	4.13	21
Pennsylvania[1]	7.8	7.0–8.3	0.22	2.80	77
Cowpasture River valley, Bath Co., Va. Elevation 440-485 m USNM 489606-489610, 489704-489714	7.6	7.2–7.8	0.18	2.37	16
Warm Springs Mountain, Bath Co., Va. Elevation 644-1106 m USNM 489880-489884	7.8	7.5–8.0	——	——	5
White Sulphur Springs, Greenbriar Co., W. Va.[2]	7.66	7.2–8.02	——	——	10
Pisgah Forest, Transylvania Co., N. C.[2]	7.53	7.2–8.0	——	——	10
Late Pleistocene					
New Paris No. 4, Bedford Co., Pa.[1]	8.50	8.1–8.9	——	——	2
Natural Chimneys, Augusta Co., Va.[1]	8.31	8.0–8.7	——	——	4
Clark's Cave, Bath Co., Va.	8.66	8.2–9.1	0.26	3.06	15
		Total length, mandible (including incisor)			
Recent:					
Minnesota[1]	16.2	14.9–17.6	0.67	4.13	19
Pennsylvania[1]	15.15	14.6–16.0	0.32	2.09	17
Cowpasture River valley, Bath Co., Va. (data above)	15.3	14.8–15.9	0.16	1.04	16
Warm Springs Mountain, Bath Co., Va. (data above)	15.2	14.6–15.6	——	——	5
Late Pleistocene:					
New Paris No. 4, Bedford Co., Pa.[1]	15.3	13.8–17.2	0.88	5.74	29
Clark's Cave, Bath Co., Va.	16.6	15.5–18.4	0.50	3.00	52
		Length of dentary (from condyle)			
Recent:					
Cowpasture River valley, Bath Co., Va. (data above)	12.4	11.9–13.1	0.47	3.79	15
Warm Springs Mountain, Bath Co., Va. (data above)	12.2	11.9–12.4	——	——	5
Late Pleistocene:					
Clark's Cave, Bath Co., Va.	13.3	12.3–15.2	0.54	4.05	60

[1]Data from Guilday *et al.*, 1964.
[2]Data from Ray, 1967, Table 2.

Table 9. Measurements (in mm) of *Blarina brevicauda*, various localities (continued).

Locality	X̄	OR	SD	CV	N
	p4 – m3, Antero-posterior Crown Length[3]				
Recent:					
Minnesota[1]	6.29	5.8–6.6	0.19	3.02	20
Pennsylvania[1]	6.06	5.7–6.3	0.19	3.13	24
Cowpasture River valley, Bath Co., Va. (data above)	6.1	5.9–6.3	0.22	3.60	16
Warm Springs Mountain Bath Co., Va. (data above)	6.2	6.0–6.3	——	——	5
White Sulphur Springs, Greenbrier Co., W. Va.[2]	5.85	5.48–6.19	——	——	10
Pisgah Forest, Transylvania Co., N. C.[2]	5.78	5.47–5.98	——	——	10
Late Pleistocene:					
New Paris No. 4, Bedford Co., Pa.[1]	6.14	5.5–6.8	0.39	6.48	36
Natural Chimneys, Augusta Co., Va.[1]	6.43	6.2–6.6	0.13	2.02	9
Clark's Cave, Bath Co., Va.	6.56	6.2–6.9	0.14	2.13	57
	Width, mandibular condyle				
Recent:					
Minnesota[1]	4.16	3.9–4.6	0.19	4.56	22
Pennsylvania[1]	3.85	3.7–4.1	0.13	3.37	24
Cowpasture River valley, Bath Co., Va. (data above)	3.89	3.7–4.2	0.18	4.62	16
Warm Springs Mountain, Bath Co., Va. (data above)	3.89	3.8–4.0	——	——	5
Late Pleistocene:					
New Paris No. 4, Bedford Co., Pa.[1]	3.91	3.3–4.5	0.30	7.67	37
Clark's Cave, Bath Co., Va.	4.01	3.49–4.65	0.20	5.03	13

[1]Data from Guilday *et al.*, 1964.
[2]Data from Ray, 1967, Table 2.
[3]Defined as C_1-M_3 in Guilday *et al.*, 1964. (See Repenning, 1967 for terminology).

ing clues to the minimum date of deposition. *Blarina* occurred continuously from boreal times to the present in the area. During this time span it diminished in size. If deposition had continued undiminished, remains of this shrew would have been expected to reflect this. They did not. From an inspection of the measurements in Table 9 and the low coefficient of variation from the Clark's Cave sample, it is apparent that the deposit was composed primarily of large individuals—the minimum measurements recorded exceed the average of Recent *B. b. kirtlandi.* This size difference is clearly brought out by comparing the measurements of the Clark's Cave *Blarina* sample with those from Recent examples from the Cowpasture River valley taken by Charles O. Handley, Jr. and his students (Table 9). It would appear that all short-tailed shrews, and by extension the bulk of the deposit, accumulated prior to any diminution in size, and that deposition threrefore ceased at that spot by the close of late Pleistocene times, or if deposition continued to occur, it was not on a sustained basis.

The large size of the short-tailed shrew remains is indicative of more boreal conditions, but its wide choice of habitats, occupying practically all terrestrial habitats within the forested East, are too broad to provide any specific ecological clues. Short-tailed shrews range north to the shores of James Bay.

Remains of this shrew were conspicuously absent from the lower levels of the stratified New Paris No. 4, Pa., deposit. These lower levels produced only boreal mammals, and it appears that at that site, the short-tailed shrew was absent during full glacial times, becoming common only with the return of more temperate conditions. But it may have been present at that time at Clark's Cave, two degrees latitude to the south. Further collections may clarify the situation.

Family: Talpidae—Moles

Parascalops breweri (Bachman)—Hairy-tailed Mole

MATERIAL: CM 24537. 2 partial skulls; 8 left, 7 right mandibles; 11 left, 12 right humeri. MNI = 12 individuals.

Scalopus aquaticus (Linnaeus)—Eastern Mole

MATERIAL: CM 24539. 1 partial right mandible, no dentition; 1 left humerus. MNI = 1 individual.

Condylura cristata (Linnaeus)—Star-nosed Mole

MATERIAL: CM 24538. 12 left, 4 right partial mandibles; 11 left, 13 right humeri; 1 rostrum. MNI = 13 individuals.

REMARKS: Moles (0.9% of all terrestrial mammals) were rare in the deposit. Their secretive habits protect them from aerial predation. The eastern mole, *Scalopus,* was represented by a single individual. The hairy-tailed mole, *Parascalops* (46%), and the star-nosed mole, *Condylura* (50%), were present in equal numbers. This is in striking contrast to the situation at Sheep Rock Shelter, Pa., 300 km north of Clark's Cave, where *Scalopus* accounted for 89% of all moles, *Condylura* 9%, and *Parascalops* but 2.8%. The modern ecological situation is much the same at both sites, a narrow intermontane flood plain between high, parallel, oak-forested ridges in the Atlantic drainage. The high numbers of *Scalopus* at Sheep Rock, compared with the situation at Clark's Cave is, we believe, due to the relative age of the two sites. Sheep Rock Shelter is a Recent owl roost uninflueneed by late Pleistocene climatic changes.

Both *Parascalops* and *Condylura* occur in western Virginia today (Handley & Patton, 1947). They probably do not occur as low as Clark's Cave or, if so, rarely. *Scalopus,* however, should occur in the extensive flat flood plain of the Cowpasture River above and below the site within cruising range of the Clark's Cave owl population. Its relative rarity in the fossil deposit is an indication of the predominantly boreal conditions reflected by the fossil assemblage. The fact that *Scalopus* was taken in such large numbers relative to *Parascalops* and *Condylura* at Sheep Rock indicates that the eastern mole was as susceptible to owl predation as the other two species of moles. Its scarcity in the Clark's Cave deposit must reflect the true picture at the time of deposition. Moles were relatively more common at Sheep Rock (12% of mammals against 0.9% at Clark's). This reflects differences in excavation technique. The total recovery attempted at Clark's Cave resulted in larger numbers of other small mammals from the sample.

Parascalops and *Condylura* have similar modern ranges in the Appalachian Mountains and adjacent plateau country of eastern North America north to the southern portion of the Canadian Shield. *Parascalops* is found no farther north than Maine. *Condylura* ranges north to James Bay and southern Labrador. Both had more extensive ranges during the boreal phase of the Wisconsinan. *Parascalops* has been reported from Robinson Cave in central Tennessee, and *Parascalops* and *Condylura* from Crankshaft Pit in the Ozark Highlands of southeastern Missouri. The range of *Scalopus,* on the other hand, is austral, including all the southern and central United States north to Minnesota, Michigan, and Massachusetts. It enters the Appalachians only in areas where it can follow the low altitude flood plains and rivers that traverse the mountain ridges.

The one *Scalopus* humerus measures 14.8 mm in length and 12.5 mm in width, well within the range of *S. a. aquaticus,* the race living in the state today (Guilday, 1961a:117, Table 1, for comparative measurements).

Adult males of both the star-nosed and the hairy-tailed moles are larger than females. The Clark's Cave samples are too small to adequately express the true extent of variation, but they do suggest sexual size differences as in the living animals. This is reflected by the slightly larger coefficient of variation of p4-m3 of the Clark's Cave *Condylura,* com-

Table 10. Measurements (in mm) of *Condylura cristata* and *Parascalops breweri.*

Locality and age	$\bar{X}$	OR	SD	CV	N
		Condylura cristata Alveolar length p4 – m3			
Recent:					
Pennsylvania, males (CM 23864-71, 23874-5, 23877-80)	6.3	6.1–6.6	0.15	2,37	14
Late Pleistocene:					
Clark's Cave, Va.	6.8	6.5–7.2	0.23	3.37	16
		Maximum length, humerus			
Recent:					
Pennsylvania, males	13.0	12.8–13.2	——	——	6
Late Pleistocene:					
Clark's Cave, Va., females?	13.1	12.8–13.4	——	——	11
Clark's Cave, Va., males?	13.9	13.8–14.3	——	——	8
Clark's Cave, Va., sexes combined	13.4	12.8–14.3	0.46	3.46	19
		Parascalops breweri Maximum length, humerus			
Late Pleistocene:					
Clark's Cave, Va., males?	14.6	14.0–15.2	——	——	10
Clark's Cave, Va., females?	13.4	13.2–13.7	——	——	5
Clark's Cave, Va., sexes combined	14.2	13.2–15.2	0.65	4.58	15

pared with the same measurement in a sample of Recent males, and in the bimodal distribution of the total length of *Condylura* humeri. The Clark's Cave *Condylura* humeri fell into two size classes, with no overlap in their observed ranges (Table 10): females? 12.8-13.4, males? 13.8-14.3. An alternate explanation, that the Clark's Cave sample is eomposed of two intermingled populations, a larger late Pleistocene and a smaller Recent form, was rejected because a similar situation could not be demonstrated in those species, *Blarina brevicauda,* for example, where a significant sexual size difference does not occur.

Humerus length of six Recent male *Condylura* (Table 10), the larger sex, fell within the range of the Clark's Cave presumed females and were significantly smaller than those of presumed males from the deposit. The Recent males averaged some 6.5% smaller than the Clark's Cave males?, suggesting that the late Pleistocene population, as at New Paris No. 4, Pa., was indeed larger in body size than its modern regional counterpart.

In the case of *Parascalops*, little, if any, size difference can be shown. Sexual size differences are suggested by the relatively broad observed range of humeri (Table 10), but the sample is too small to be other than suggestive.

Order: Chiroptera—Bats

Family: Vespertilionidae—Evening Bats

At least 1,554 individual bats were represented, and their remains formed 36% of the total mammalian assemblage at the site. Bats are not usually represented in raptor prey. Their high numbers at Clark's Cave reflected the presence of a large bat colony in the cave itself. Gillette and Kimbrough (1970:265) cite instances of bat predation by raptors, "groups of hawks or falcons working together in a small area with devastating effectiveness on emerging or returning colonies." The nocturnal feeding habits of bats and owls bring them into contact with greater frequency, and owl predation on bats is well-documented (Hall & Blewett, 1964). The roost site, ideal for birds of prey, is too shallow and exposed to have served as a hibernaculum, and most of the excavated bat bones are presumed prey items derived from the large bat population deep in the cave itself.

Genus *Myotis* Kaup—Little Brown Bats

MATERIAL: CM 24599-24619. 2,309 whole or partial mandibles.

1,000 of the most complete are grouped in lots according to alveolar length of lower toothrow, c-m3, in 0.1 mm increments. Additional material, unmeasured mandibles, skull fragments etc., under CM 24626-24628. A minimum of 877 *M. lucifugus*, *M. sodalis*, or *M. keenii* based upon 76% of all *Myotis*. A minimum of 138 *M.* cf. *leibii* based upon 12% of all *Myotis*. A minimum of 138 *M.* cf. *grisescens* based upon 12% of all *Myotis*.

REMARKS: All identifications are based upon lower jaws. Alveolar length of lower toothrow c-m3 of 1,000 specimens is shown in the graph in Fig. 16. The Clark's Cave *Myotis* sample is composed of three subgroups based upon size. A trimodal curve results with modes at 5.4, 5.8, and 6.6 mm. These could be related to modern eastern North American species. The smaller group, mode 5.4 mm, about 12% of the *Myotis* in the sample, is *Myotis* cf. *leibii*, Leib's bat. Although never a common species, Leib's

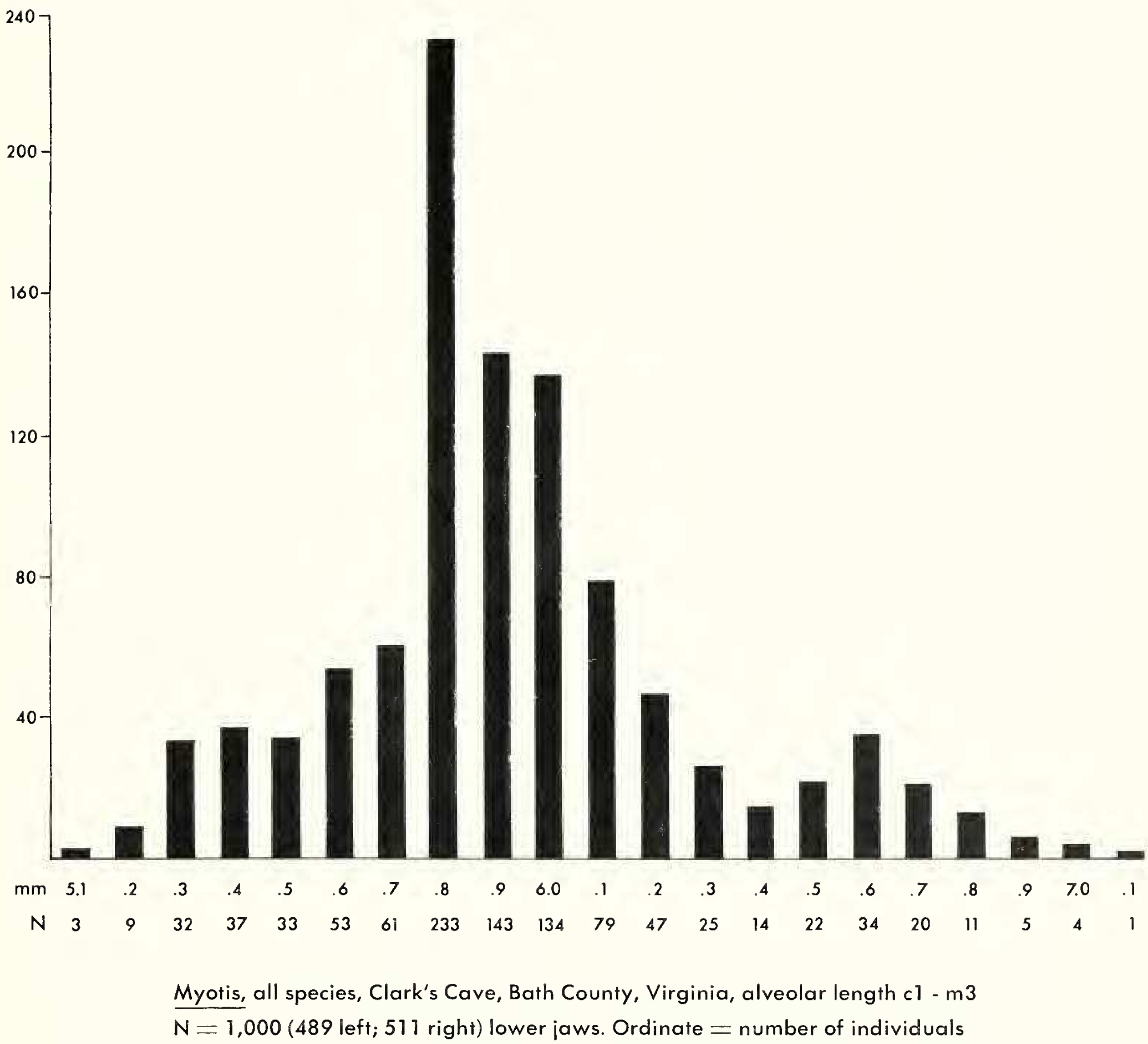

Fig. 16. Histogram. Measurements in millimeters of mandibles of various species of bats, *Myotis*, from Clark's Cave, Bath County, Virginia.

bat is broadly distributed in the East from Maine and southern Quebec south to western Virginia (Hall & Kelson, 1959). Not listed as a member of the fauna of Virginia by Handley & Patton, 1947, it has subsequently been reported from Millboro Cave, Bath County, and Hupman's Saltpeter Cave, 750 m elevation, in neighboring Highland County (Johnson, 1950), and present but rare, in Starr Chapel and Porter's Caves, Bath County (Holsinger, 1964). Four specimens were netted at entrance No. 3 of Clark's Cave in August, 1974, by C. O. Handley, Jr.

The larger subgroup, mode 6.6 mm, estimated as 12% of all *Myotis,* is *M.* cf. *grisescens,* the gray bat. This bat has been reported only in extreme southwestern Virginia, Grigsby Cave, in Scott County (Holsinger, 1964). It has been recorded as a fossil north and east of its present range from Cumberland Cave, Md., and Organ-Hedricks, Windy Mouth, and Patton Caves, W. Va. (Handley, 1956a:251). These records, coupled with the evidence of a sizeable former population in Clark's Cave, suggest a range shift to the southwest since late Pleistocene times.

By far the bulk of the *Myotis,* about 75%, fell within an intermediate range. Inspection of this curve, mode 5.8 mm, indicates that unlike the other two, which appear symmetrical, it is strongly skewed to the left. There are at least two and possibly three species of *Myotis* represented here: *M. lucifugus,* the little brown bat; *M. sodalis,* the social bat; and *M. keenii,* Keen's bat. At the present time, *M. lucifugus* is the commonest northeastern cave bat, *M. keenii* is moderately common, and *M. sodalis* is uncommon. During the years 1946-1951, six *M. lucifugus* were collected for each *M. keenii* in Pennsylvania (Roberts & Early, 1952). There is some evidence that *M. keenii* may have been relatively more common during the late Pleistocene in Pennsylvania, at least. New Paris sinkhole No. 4 yielded the remains of 302 *M. keenii,* but only 225 *M.* cf. *lucifugus* or *sodalis* (Guilday *et al.,* 1964:151). The fact that the frequency curve is skewed towards the small end of the scale suggests that the commonest component species was probably *M. lucifugus* (or *M. sodalis)* and that the larger *M. keenii* was the minority species. No attempt was made to assign a specific identification to particular specimens because of the extensive overlap in measurements in modern samples and the poor state of preservation of the fossils. Holsinger, 1964, records *M. keenii, M. lucifugus,* and *M. sodalis* from Bath County caves.

Pipistrellus subflavus (F. Cuvier)—Pipistrelle Bat

MATERIAL: CM 24620. 26 left, 19 right mandibles. MNI = 26 individuals.

REMARKS: Pipistrelles comprised only 1.2% of the total number of bats recovered. In contrast, they formed 53% (45 out of 84 bats) of a mist-net sampling run for three hours at entrance no. 3 of Clark's Cave in August, 1974. Alveolar length c-m3, mm followed by (N): 4.5(1), 4.6(8), 4.7(5), 4.8(16), 4.9(3), 5.0(5), 5.1(1).

Eptesicus fuscus (Palisot de Beauvois)—Big Brown Bat

MATERIAL: CM 24624, 24625. 341 left, 363 right mandibles, partial skulls and fragments. MNI = 363 individuals.

REMARKS: The big brown bat is a common species at the cave today. It comprised 15% (13 out of 84) of the mist-netted bats, August, 1974.

Lasiurus cf. *borealis* (Muller)—Red Bat

MATERIAL: CM 24621. 3 left, 2 right mandibles. MNI = 3 individuals.

REMARKS: Although this tree bat is one of the commonest of eastern North American bats, it is not normally a cave-frequenting species and would not be captured with any frequency at the cave entrance by birds of prey. Alveolar length c-m3, mm followed by (N): 5.1(1), 5.3(1), 5,8(2), 5.9(1).

Plecotus E. Geoffroy Saint Hilaire—Big-eared Bats

MATERIAL: CM 24622. 9 left, 7 right mandibles. MNI = 9 individuals.

REMARKS: Two Recent species of big-eared bats have been reported from Virginia, *P. rafinesquii* Lesson and *P. townsendii* Cooper. *P. rafinesquii* is a bat of the southeastern United States and the Mississippi Valley as far north as Ohio. The sole Virginia record is from Dismal Swamp on the coastal plain (Handley, 1959:161). It has been collected in the Appalachians just west of the state, however, in eastern Tennessee, Kentucky, and West Virginia (Collison Cave, Nicholas Co., Handley, 1959:165).

The only Recent record of a big-eared bat from the mountainous western portion of the state is of *P. townsendii,* the western big-eared bat. There is a thriving population of this bat in the central Appalachians, separated by some 960 km from the Ozark Mountain segment of its range. According to Handley they have been reported from at least 19 caves from the West Virginia highlands within an area 48 km wide and 64 km long (*ibid*:202) north of Clark's Cave, with an isolated station 240 km southwest in Tazewell County, Va. Holsinger, 1964, reports *P. town-*

sendii from caves of over 600 m elevation from Highland and Bath counties, Virginia.

The Clark's Cave specimens, fragmentary mandibles, could have been either species. Mandibles of a third species, the extinct *P. alleganiensis* described from the mid-Pleistocene Cumberland Cave deposit, are not distinguishable from modern species of *Plecotus*. But Cumberland Cave clearly antedates the Clark's Cave deposit (Gidley & Gazin, 1938). Bats of the genus *Plecotus* have also been reported from Frankstown Cave, a Pleistocene fissure deposit in the Ridge and Valley section of central Pennsylvania (Guilday, 1961b).

Handley, 1959, regards the disjunct Appalachian distribution of *P. townsendii* as a relict of a more extensive past distribution. Its isolation is reflected in its recognition as a distinct subspecies, *P. t. virginianus*.

The big-eared bat population of Clark's Cave was never a large one. The few remains from the fossil deposit, representing only 9 individuals, or 0.6% of the fossil bat fauna, may have been from itinerant individuals.

Order: Lagomorpha—Rabbits, Hares, Pikas
Family: Leporidae—Rabbits and Hares

Sylvilagus cf. *transitionalis* (Bangs)—
New England Cottontail

MATERIAL: CM 24591. Partial left innominate, distal end of left femur. MNI = 1 individual.

REMARKS: The minimum number of all leporids from Clark's Cave is 27 (1% of all terrestrial mammals). All but one, based on the two fragments listed above as *S. transitionalis*, are referred to snowshoe hare. The *S. transitionalis* bones are small (Table 11), too small for snowshoe hare or common cottontail *S. floridanus*. The diagnostic supraorbital processes were not preserved, so the identification, based solely on size, is provisional.

Handley & Patton, 1947:189, state that *S. transitionalis* is found at higher elevations throughout the mountainous portions of the state, probably not below 750 m elevation. It is sympatric with *Lepus americanus* in Virginia today. Bailey, 1946:282, specifically lists Bath County in the modern range.

Fossil or subfossil remains have also been reported from New Paris No. 4, Pa., and Ladds Quarry, Ga.

Lepus americanus Erxleben—Snowshoe Hare

MATERIAL: CM 24590. 18 left, 14 right premaxillae (14 retaining first incisors); 32 isolated first upper incisors; 2 left, 2 right frontals; 10 left, 8 right maxillae; 1 occipital; 17 left, 13 right mandibles; 9 atlas vertebrae; 21 left, 15 right scapulae; 12 left, 10 right humeri; 14 ulnae; 4 radius; 21 right, 6 left innominates; femora—16 proximal, 13 distal ends, 1 complete; 15 left, 8 right tibia; 15 left, 17 right calcanea. MNI = 23 individuals.

REMARKS: The snowshoe hare does not occur in the Cowpasture River valley or the surrounding hills today. Handley & Patton (1947:186) state that the snowshoe hare probably occurred at one time throughout the mountainous areas of the state at higher elevations. "Now known to occur only in Highland County, where it is uncommon . . . restricted to areas of spruce and fir, found in open woods and thickets."

Characters differentiating *Lepus* from *Sylvilagus* included shape of the supraorbital processes, the occipital, the posterior margin of incisive foramen, the rugosity of the zygoma, and the relative slenderness of shafts of humerus, femur, and tibia.

Although most of the lagomorph material was so fragmentary that specific, even generic, identification was not possible, all, with the exception of two elements identified as New England cottontail, CM 24591, are referred to *Lepus americanus* for the following reasons: (1.) All preserved diagnostic parts were *Lepus;* (2.) Measurements average slightly larger than late Pleistocene specimens of *L. americanus* from New Paris No. 4, Pa.

The complicating factor in identification is that gross size cannot be used in separating *L. americanus* from *Sylvilagus floridanus*. Modern *L. a. virginianus* from the central Appalachians is easily distinguished from *Sylvilagus* by virtue of its larger size, but late Pleistocene populations of *L. americanus*, like those at New Paris No. 4, Pa., are as small as modern *Sylvilagus* from the same area. They are indistinguishable on the basis of size alone.

Order: Rodentia—Rodents
Family: Sciuridae—Squirrels

Tamias striatus (Linnaeus)—Eastern Chipmunk

MATERIAL: CM 24533. 22 left, 24 right whole or partial mandibles; 5 left, 4 right maxillae. MNI = 24 individuals.

REMARKS: The eastern chipmunk is common throughout the state at all altitudes and in all types of brushy or forested situations today (see Handley & Patton, 1947 for exceptions). It is also common in the Clark's Cave deposit, comprising 22% of the eight species of sciurids from the deposit.

The Clark's Cave sample is composed of chipmunks larger in size than present mid-Appalachian forms (Table 12). They agree in size with both the late Pleistocene sample from New Paris No. 4, Pa., and the largest living subspecies, *T. s. pipilans* (Table 12).

Tamias striatus from the Appalachians exhibits a negative Bergmann's Response. It *increases* in size with *decreasing* latitude. Specimens from Quebec at the northern extremity of its northeastern range average 5% smaller in total length of skull than specimens from western North Carolina (Table 12). Individuals of *T. s. pipilans* from Louisiana, the largest subspecies, may be as much as 12.5% larger

Table 11. Measurements (in mm) of *Lepus americanus, Sylvilagus floridanus* and *Sylvilagus transitionalis*.

Locality	$\bar{X}$	OR	N
Distal width of humerus			
Lepus americanus, Recent, Pa.	10.1	9.5–10.5	6
Lepus americanus, New Paris No. 4, Pa. late Pleistocene	8.3	7.5–9.1	28
Lepus americanus, Clark's Cave, Va. late Pleistocene	8.8	8.3–9.5	18
Sylvilagus floridanus, Recent, Pa.	8.1	7.7–8.6	10
Sylvilagus transitionalis, Recent, Mass.	7.5	7.3–7.7	2
Anterior-posterior diameter of acetabulum			
Lepus americanus, New Paris No. 4, Pa., late Pleistocene	7.8	7.0–8.4	20
Lepus americanus, Clark's Cave, Va. late Pleistocene	7.95	7.4–8.9	16
Sylvilagus floridanus, Recent, Pa.	8.2	7.5–9.1	9
Sylvilagus transitionalis, Recent, Mass.	7.7	7.0–8.4	2
Sylvilagus cf. *transitionalis*, Clark's Cave, Va., late Pleistocene	6.5	---------	1
Distal width of femur			
Lepus americanus, Recent, Pa.	15.4	14.8–16.4	7
Lepus americanus, New Paris No. 4, Pa. late Pleistocene	13.2	12.4–14.3	20
Lepus americanus, Clark's Cave, Va. late Pleistocene	13.4	12.3–14.5	11
Sylvilagus floridanus, Recent, Pa.	13.4	12.8–13.8	10
Sylvilagus transitionalis, Recent, Mass.	12.0	11.7–12.3	2
Sylvilagus transitionalis, Clark's Cave, Va., late Pleistocene	11.5	-------	1
Distal width of tibia			
Lepus americanus, Recent, Pa.	13.5	12.4–14.5	7
Lepus americanus, New Paris No. 4, Pa., late Pleistocene	11.2	11.0–11.5	9
Lepus americanus, Clark's Cave, Va., late Pleistocene	11.7	11.0–12.8	18
Sylvilagus floridanus, Recent, Pa.	11.2	11.0–11.6	5
Sylvilagus transitionalis, Recent, Mass.	10.3	-------	1

Measurements by W. Pollock and A. Guilday.

Specimens examined:

Lepus americanus, Recent, Pa.: CM 2212, 2211, 2213, 2214, 2215, 2217, 2216, 33286, 33284, 33285, G-644; New Paris No. 4, Pa., late Pleistocene: CM collections; Clark's Cave, Va., late Pleistocene: CM 24590.

Sylvilagus floridanus, Recent: CM 27007, 27008, 27010, 27012, 7951, 7952, 8363, 10673, 19365, 35790, 10137, 7651, G-8.

Sylvilagus transitionalis: no number, Guilday collection, Mass.; Clark's Cave, Va., late Pleistocene: CM 24591.

in total length of skull (USNM 28459, Ray, 1965: 1020) than average Quebec specimens.

Unfortunately, comparable measurements could not be taken from the fragmentary Pleistocene specimens, but those from Clark's Cave average 8% larger in alveolar length of lower toothrow than modern Pennsylvania specimens of *T. s. fisheri*. Although the eastern chipmunk does become smaller toward the north in the eastern portion of its range, it becomes larger at all latitudes toward the west. It is possible that the superior size of the late Pleistocene *T. striatus* from the mid-Appalachians may be a reflection of the same environmental conditions that accounted for the influx of so many midwestern forms into the Appalachians at that time.

At Clark's Cave and Natural Chimneys, Va., remains of nocturnal, arboreal flying squirrels exceeded those of terrestrial, diurnal chipmunks 2/1 and 3/1 respectively. At New Paris No. 4, Pa., the reverse was true. Chipmunk remains outnumbered those of flying squirrels by 2/1. Marked changes in the relative percentages of species from two or more sites sampling the same temporal fauna in the same general geographic area, in this case the mid-Appalachians, reflect either differing habitats, predator preferences, or methods of deposition. The Clark's Cave and Natural Chimneys deposits were formed largely by owls, which accounted for a large number of nocturnal flying squirrels in comparison with the number of diurnal chipmunks. At New Paris No. 4, Pa., animals were trapped in an open tumble-in sinkhole, resulting in higher numbers of terrestrial, as opposed to arboreal, forms. Predator bias was not a factor at New Paris No. 4, so nocturnal forms were not selected, as in the case of the owl roost sites.

Eutamias minimus (Bachman)—Least Chipmunk

MATERIAL: CM 24532. 2 left mandibles with full dentition; 1 left, 1 right mandible with p4-m1. MNI = 3 individuals.

REMARKS: The least chipmunk has not previously been reported from the Appalachians, either fossil or Recent. It occurs in western and central North America, usually in open to brushy, boreal, coniferous forest situations, and reaches its greatest

Table 12. Measurements (in mm) of *Tamias striatus*.

Locality and taxa	$\bar{X}$	OR	SD	CV	N
		Alveolar length, p4 – m3			
Recent:					
T. striatus pipilans[1]	6.76	6.3–7.4	0.30	4.40	19
New Paris No. 2, Pa. (1,875 yrs. B.P.)	6.28	5.8–6.8	0.18	2.86	114
Late Pleistocene:					
New Paris No. 4, Pa. (11,300 yrs. B.P.)	6.74	6.3–7.1	0.20	6.67	30
Hartman's Cave, Pa.[1]	6.90	6.2–7.7	0.42	6.11	9
Clark's Cave, Va.	6.81	6.5–7.3	0.21	3.08	28
Robinson Cave, Tenn.	7.5	7.3–7.8	——	——	2
		Total length of skull			
Recent:					
T. s. quebecensis, Quebec[3] 48° 30'N. lat.	39.1	37.4–40.0	——	——	4
T. s. lysteri, Ontario[2] 43° 30'N. lat.	39.4	38.0–40.1	——	——	7
T. s. fisheri, N.Y.[2] 41° N. lat.	40.1	38.8–41.0	——	——	10
T. s. striatus, N.C.[2] 34° N. lat.	41.1	39.8–42.6	——	——	11
Pleistocene:					
T. aristus, Ga.[1] 34° N. lat.	52.7	——	——	——	1

Measurements from Ray, 1965[1]; Howell, 1929[2]; Cameron, 1950[3].

abundance in open, sandy, pine and spruce parklands. It is not found in the United States east of Wisconsin. But north of the Great Lakes it occurs across the southern half of Ontario east to extreme western Quebec, 800 km north of Clark's Cave (Banfield, 1974), as shown in Fig. 17.

Identification, based upon dentitions, both lower and (Back Creek Cave No. 2, Va.) upper, is firm to genus. Referral to *E. minimus* is based on small size, geographic proximity, and ecological probability.

The eastern chipmunk *(Tamias),* an inhabitant of deciduous forest and brushland, and the least chipmunk (*Eutamias*) coexist today in a broad area of east-central Canada extending from southern Manitoba and northern Wisconsin and Minnesota toward the east and north of the Great Lakes for 650 km across the southern half of Ontario (Fig. 18). Where the two occur in the same general area, *Tamias* prefers deciduous, *Eutamias* coniferous, forest situations. Their remains also have been found together at the 7,000 to 7,500-year B.P. levels at

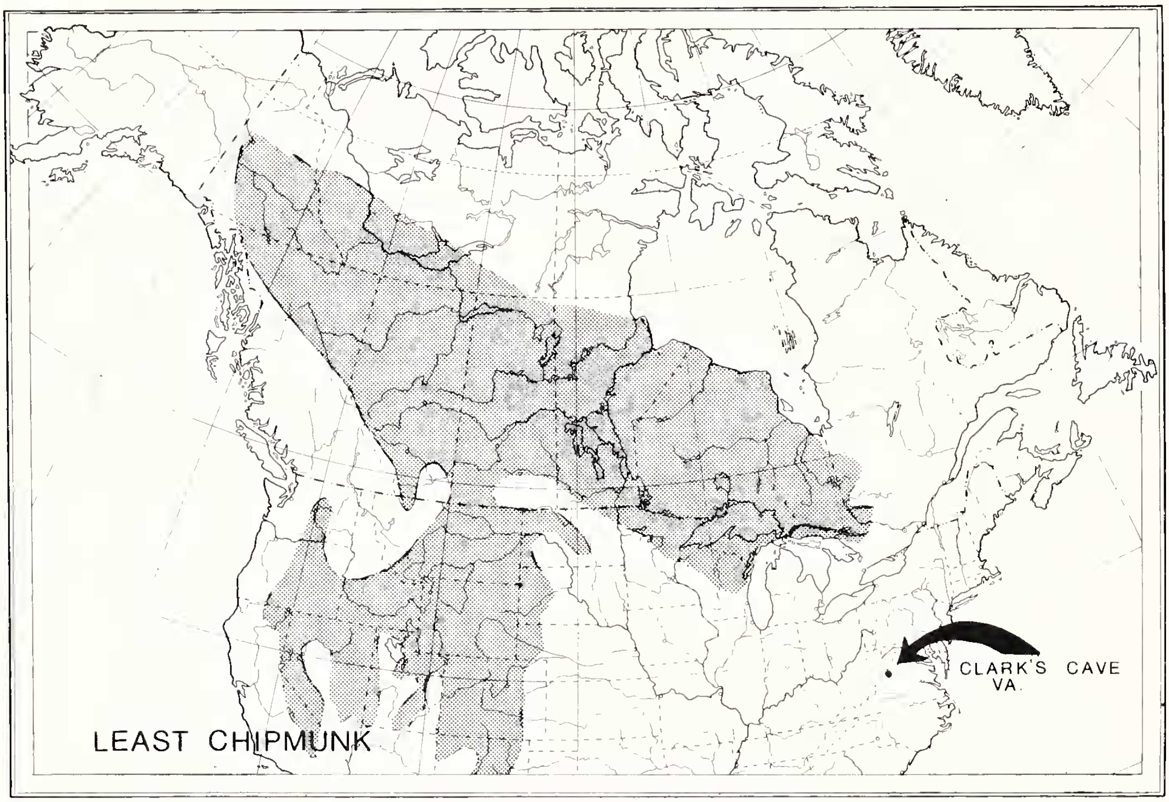

Fig. 17. Modern range of least chipmunk, *Eutamias minimus* (Bachman), adapted from Hall & Kelson, 1959. Present in Clark's Cave local fauna.

Table 13. Measurements (in mm) of *Eutamias* cf. *minimus*, late Pleistocene.

Locality and measurement	$\bar{X}$	OR	N
Clark's Cave, Va.			
p4 - m3, alveolar length	5.38	5.33–5.40	4
p4 - m3, occlusal length	4.85	4.75–4.95	4
Back Creek Cave No. 2, Va.			
P3 - M3, occlusal length	c. 5.33	------	1

the Itasca Bison Kill Site in northcentral Minnesota (Shay, 1971).

Eutamias minimus is now known from one other Appalaehian cave site, a raptor-roost deposit of similar age, Back Creek Cave No. 2, Va., 24 km southwest of Clark's Cave (CM 29727, maxilla with P3-M2).

This strictly diurnal hibernating rodent would not be expected to bulk as large in the deposit as nocturnal small mammals active the year round. It is possible that this small, mouse-size ground squirrel may have been more common than its remains would indicate.

Marmota monax Linnaeus—Woodchuck

MATERIAL: CM 24527. 1 right 1 left mandible; skull fragments. MNI = 2 individuals.

REMARKS: A common species in late Pleistoeene Appalachian cave deposits, this large terrestrial ground squirrel ranges throughout the deciduous and coniferous woodlands of east-central and northern North America north to Alaska and Labrador. Occlusal length p4-m3 is 18.9 mm.

Spermophilus tridecemlineatus (Mitchill)—13-lined Ground Squirrel

MATERIAL: CM 24531. 5 left, 5 right whole or partial mandibles; 2 right maxillae. MNI = 5 individuals.

REMARKS: Remains of the 13-lined ground squirrel are generally distributed in eastern North American periglacial cave sites where they form from 4% to 10% (over 90% at Welsh Cave, Ky.) of the sciurids recovered. Remains are known from at least six other late Wisconsinan sites east of their present range: New Paris No. 4, Pa.; Bootlegger Sink, Pa.; Eagle Cave, W. Va.; Natural Chimneys, Va.; Welsh Cave, Ky.; Robinson Cave, Tenn. They have also been reported from Cumberland Cave, Md., late Kansan in age. The 13-lined ground squirrel was apparently common and widespread throughout the East during late glacial times, a distinct indicator of semi-prairie or parkland conditions.

Remains of this nominally midwestern ground squirrel occur with those of the eastern chipmunk and the least chipmunk at Clark's Cave. These three species of ground squirrels coexist today only in a relatively small area, stretching from northern Wisconsin north and west of the Great Lakes to southern Manitoba, from 1,200 km to 2,400 km northwest of Clark's Cave (Fig. 18). This area defines the present day boundary between eastern coniferous/deciduous forest and grassland (Cushing, 1965), the Illinoian and Canadian Biotic Zone contact of Dice, 1943. In this area today the chipmunk, *Tamias striatus* (deciduous woodland preference), the least chipmunk, *Eutamias minimus* (coniferous woodland preference), and the 13-lined ground squirrel, *Spermophilus tridecemlineatus* prairie preference), find an intermesh of habitats enabling them to occur sympatrically, if not on identical ground, at least in such proximity that they can be harvested by raptors operating from a single roost, as at Clark's Cave.

Alveolar length of P3-M3 from one individual was 7.46 mm. Alveolar length of p4-m3 from eight examples was $\bar{X}$ 7.76 mm (OR was 7.37-8.2).

Sciurus cf. *carolinensis* Gmelin—Gray Squirrel

MATERIAL: CM 29612. 1 left M2 (unerupted); 1 right M2 or M3 (extreme tooth wear); 1 M3 (slight tooth wear); 1 left, 1 right p4; 1 left, 1 right m1; 1 right m1 or m2; 1 left 1 right m3. MNI = 3 individuals.

REMARKS: The gray squirrel found primarily in deciduous mast-producing forest was probably not a member of the boreal fauna at Clark's Cave. It is common throughout the Appalachians north to New Brunswick. Farther north only the red squirrel, *Tamiasciurus hudsonicus*, occurs.

The persistence of the gray squirrel in western Virginia during full glacial times would have been governed by the type of forest cover. Pollen analysis at Hack and Quarles Pond in the Shenandoah Valley, at approximately the same altitude as both Natural Chimneys and Clark's Cave, seems to indicate that the western valley floor of the state supported a coniferous boreal forest within which one would not expect the gray squirrel to occur (Craig, 1969).

At the New Paris Pa., sinkholes, gray squirrel was the common tree squirrel recovered from the Recent Sinkhole No. 2 fauna. Only red squirrel remains were present in the boreal late Pleistocene Sinkhole No. 4 fauna.

One maxilla of gray squirrel was recovered from the late Pleistocene Natural Chimneys, Va., local fauna (CM 7536), in association with five red squirrels. The red squirrel is also the commonest squirrel in the Clark's Cave fauna (MNI 25).

The ten molars recovered were from at least three individuals, judging from the various states of toothwear. They agree in size with modern Pennsylvania comparative material and are not large enough to be those of fox squirrel, *Sciurus niger*.

Tamiasciurus hudsonicus (Erxleben)—Red Squirrel

MATERIAL: CM 24534. 13 left, 25 right whole or partial mandibles; 8 left, 4 right maxillae; 1 premaxilla. MNI = 25 individuals.

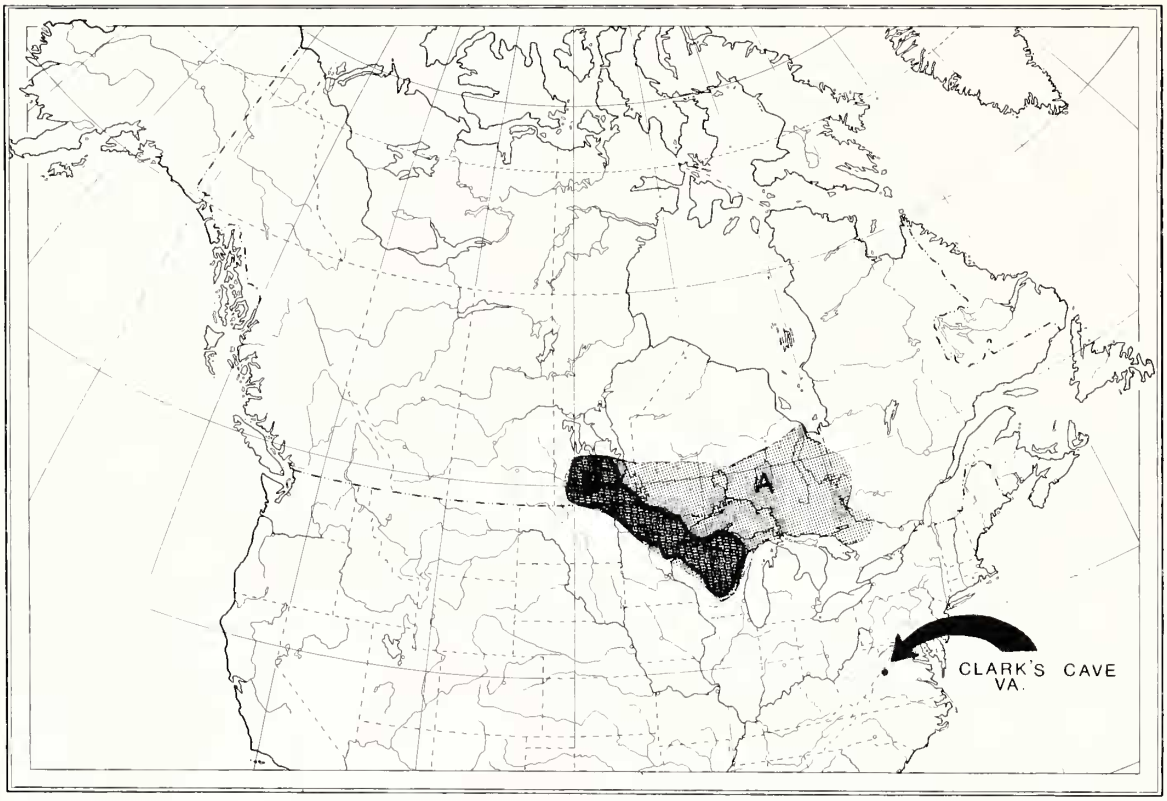

Fig. 18. Modern range overlaps of three species of terrestrial sciurids from Clark's Cave local fauna. A = overlap least chipmunk, *Eutamias minimus* (Bachman), and eastern chipmunk *Tamias striatus* (Linnaeus). B = overlap *E. minimus, T. striatus,* and 13-lined ground squirrel, *Spermophilis tridecemlineatus* (Mitchell).

REMARKS: The common large tree squirrel of Appalachian late Pleistocene sites, the red squirrel, accounted for 26% of the sciurids from the deposit. The red squirrel, the most widely distributed North American sciurid, ranges throughout the northern boreal forest from Alaska to Labrador, south in the Rocky Mountains to New Mexico in the West, in the Appalachian Mountains to North Carolina in the East. Commonest in coniferous forests, it is a very adaptable squirrel, and may occur in deciduous hardwood south to Iowa, Illinois, and North Carolina (Hall & Kelson, 1959). It occurs at the site today.

The Clark's Cave material is so fragmentary that the only measurements that could be taken were alveolar length of P4-M3 and p4-m3. P4-M3, one observation, was larger than that of thirty modern examples of *T. h. loquax* from Pennsylvania (Table 14). It was comparable in size to specimens from northwestern North America. Measurements of p4-m3 also indicate a large form, although this measurement is difficult to take with consistency, and is biased toward larger size by the sloping p4 and erosion of the anterior alveolar wall. Alveolar length of p4-m3 may exceed occlusal length by as much as 0.5 mm, but even when this correction is made it is evident that the Clark's Cave *Tamiasciurus* material is of larger size than Recent eastern specimens, and is comparable to Recent Northwestern and late Pleistocene New Paris No. 4, Pa. material.

Genus *Glaucomys* Thomas—Flying Squirrels
Glaucomys sabrinus (Shaw)—
Northern Flying Squirrel

MATERIAL: CM 24529. 28 left, 22 right whole or partial mandibles; 8 left, 13 right maxillae. MNI = 28 individuals.

Glaucomys volans (Linnaeus)—
Southern Flying Squirrel

MATERIAL: CM 24530. 15 left, 19 right whole or partial mandibles; 1 left, 2 right maxillae. MNI = 19 individuals.

REMARKS: Flying squirrels comprised about 42% of the eight species of sciurids from the deposit, and 63% from Natural Chimneys, Va., high figures that clearly reflect the activity of nocturnal birds of

Table 14. Measurements (in mm) of *Tamiasciurus hudsonicus.*

Age and locality	$\bar{X}$	OR	SD	CV	N
		P4 – M3, occlusal length			
Recent:					
Pennsylvania[1]	7.37	6.7–8.1	——	——	30
Natishquan R., Que., Hamilton R., Lab.[1]	7.58	7.2–8.4	——	——	17
Hudson Bay, Que.[1]	7.75	7.5–8.1	——	——	16
Moorhead, Minn.[1]	7.85	7.2–8.4	——	——	10
Aklavik, NWT, Seward, Alaska[1]	8.09	7.7–8.4	——	——	9
Late Pleistocene:					
Clark's Cave, Va.	8.4	——	——	——	1
		p4 – m3, occlusal length			
Recent:					
Pennsylvania[1]	7.39	6.8–7.8	——	——	33
Natishquan R., Que., Hamilton R., Lab.	7.66	7.3–8.0	——	——	20
Hudson Bay, Que.[1]	7.84	7.6–8.2	——	——	15
Moorhead, Minn.[1]	7.92	7.2–8.5	——	——	11
Aklavik, NWT, Seward, Alaska[1]	8.20	8.0–8.4	——	——	9
Late Pleistocene:					
New Paris No. 4, Pa.[1]	8.20	8.0–8.3	——	——	4
		p4 – m3, alveolar length			
Late Pleistocene:					
Clark's Cave, Va.	8.68	8.15–9.2	.3	3.46	20

[1]Measurements from Guilday *et al.*, 1964.

prey. Percentages for the diurnal chipmunk (*Tamias striatus*), 23% and 14% respectively, were much lower. In contrast with these figures, derived from raptorial bird roost-litter, remains of nocturnal flying squirrels from the pit-trap sinkhole at New Paris No. 4, Pa., comprised only 19% of all squirrels, and were greatly exceeded in numbers by diurnal terrestrial chipmunks (31%).

As at other late Pleistocene cave deposits from the central Appalachians, New Paris No. 4, Pa., and Natural Chimneys, Va., there were two species of *Glaucomys* present. The larger is identified as *G. sabrinus,* the smaller species as *G. volans.* They were sharply differentiated in size, with no overlap in observed ranges, and had a mean size-differential of 16% in alveolar length of p4-m3 (Table 15).

Late Pleistocene representatives of both species are larger than those now present in the central Appalachians. Samples of *G. volans* from New Paris No. 4, Pa., Natural Chimneys, Va., and Clark's Cave, Va., average 8% larger than modern Pennsylvania specimens, although there is an overlap in the observed ranges (Table 15). Samples of *G. sabrinus* from the same cave deposits, however, average 14% larger than Recent *G. sabrinus* from the Appalachians in alveolar length of p4-m3 with no overlap in their respective observed ranges (Table 15). They do agree in size with specimens from the northern and western portions of the Recent range. Alveolar length of p4-m3 is a difficult measurement to take with accuracy because the anterior root of p4 slopes anteriorally away from the crown. In fossil specimens the anterior wall of the alveolus of p4 is often broken or eroded in varying degree. This would have the effect of lengthening the measurement. Despite this source of error, the size differential appears to be a real one. Both *G. volans* and *G. sabrinus* were larger during late Wisconsinan times in the Appalachians than are their modern counterparts, a reflection of cooler conditions, expressed as "Bergmann's Response."

Glaucomys volans occurs today throughout the state at all elevations and in all forest types (Handley & Patton, 1947). *Glaucomys sabrinus,* on the other hand, has been taken in Virginia only at the highest elevations (Handley, pers. comm.). It occurs in the mountains directly west of Bath County, in West Virginia, at elevations exceeding 900 m. It has been taken as far south, in the Appalachians, as Tennessee and North Carolina at altitudes ranging from 1,200 m to 1,500 m (Handley, 1953). *Glaucomys volans* ranges north to approximately the United States/Canadian border in eastern North America, and south to the Gulf coast. *Glaucomys sabrinus,* on the other hand, ranges throughout forested Canada and south along both the Rocky Mountain and Appalachian Mountain chains at increasingly higher altitudes. *G. sabrinus* is primarily a squirrel of northern coniferous/hardwood forests and taiga, while *G. volans* is more characteristic of deciduous temperate forests. Both overlap in distribution in the northern Great Lakes area and the central Appalachians, and may be found in the same woodlots in some mountain areas. *G. volans* occurs commonly in the Clark's Cave area today. The presence of *G. sabrinus* in such large numbers at the site is certainly indicative of former boreal conditions. The presence of *G. volans,* however, does not necessarily indicate temperate conditions, as the fossil population is separable by size from its modern equivalent. This presumably has physiological implications.

Table 15. Measurements (in mm) of alveolar length lower toothrow (p4–m3) of *Glaucomys.*

Age and locality	$\bar{X}$	OR	SD	CV	N
	Glaucomys sabrinus (Shaw)[1,2]				
Late Pleistocene:					
New Paris No. 4, Pa.	7.7	7.6–8.1	——	——	3
Natural Chimneys, Va.	7.8	7.3–8.4	——	——	14
Clark's Cave, Va.	8.0	7.6–8.6	.01	1.19	30
Robinson Cave, Tenn.	7.8	7.0–8.7	——	——	8
Recent:					
Eastern United States:					
G. s. coloratus	6.9	6.7–7.1	——	——	7
G. s. fuscus	6.7	6.5–6.9	——	——	5
G. s. macrotus	6.6	6.0–7.0	——	——	23
Canada:					
G. s. sabrinus	7.2	6.8–7.6	——	——	4
G. s. makkovikensis	7.1	6.9–7.4	——	——	2
Alaska:					
G. s. zaphaeus	7.6	7.3–7.9	——	——	5
Idaho:					
G. s. bullatus (=*bangsi*, Mayer, 1941)	8.7	8.6–8.7	——	——	7
	Glaucomys volans (Linnaeus)[3]				
Late Pleistocene:					
New Paris No. 4	6.4	——	——	——	2
Natural Chimneys, Va.	6.5	6.3–6.9	——	——	17
Clark's Cave, Va.	6.7	6.3–7.3	.18	2.67	17
Robinson Cave, Tenn., Armadillo Pit	6.3	6.2–6.6	——	——	5
Robinson Cave, Tenn., Sloth Pit	6.6	6.4–6.8	——	——	4
Recent:					
Pennsylvania[4]	6.0	5.6–6.4	——	——	38

[1]Measurements from Howell, 1918; Handley, 1953; Guilday *et al.*, 1964.
[2]Alveolar length of upper toothrow, when found in the literature, was converted to alveolar length of lower toothrow by multiplying by 0.94, a constant found to work out with modern Pennsylvania specimens.
[3]Data from Guilday, 1962; Guilday *et al.*, 1964, 1969.
[4]Unpublished measurements, J.K. Doutt, CMNH Recent mammal collection.

Family: Cricetidae—Deer Mice and Woodrats

Genus *Peromyscus* Gloger

MATERIAL: CM 24682-28685, 29571. 221 left, 163 right mandibles; skull fragments and isolated teeth. MNI = 221 individuals.

Peromyscus maniculatus (Wagner)—Deer Mouse

MATERIAL: CM 29569. 41 m1's. An estimated minimum of 117 individuals based upon percentage of identified m1's of *P. maniculatus* and *P. leucopus*.

Peromyscus leucopus (Rafinesque)—White-footed Mouse

MATERIAL: CM 29570. 37 m1's. An estimated minimum of 104 individuals based upon percentage of identified m1's of *P. maniculatus* and *P. leucopus*.

REMARKS: Remains of both *P. maniculatus* and *P. leucopus* were present in the collection in about equal numbers. Identifications were based upon dental charaeters. The first lower molar of *P. leucopus* is slightly larger (Table 16) than that of *P. maniculatus* with a greater incidence of accessory styles and lophs, a more massive bilaterally symmetrical anteroconid, and a deeper anterior anteroconid reentrant. Out of a series of 91 *Peromyscus* m1's selected at random, 14% could not be assigned to species either because of heavy toothwear or intermediate morphology. Of the remaining teeth, 41 (53%) were identified as *P. maniculatus*, 37 (47%) as *P. leucopus*.

Three nights of trapping by Dr. Charles O. Handley, Jr. and students of the University of Virginia in August, 1974, sampling talus, hilltop deciduous woods, woods-meadow ecotone, and hayfields surrounding the cave, produced 52 *P. leucopus* in 2000 trap nights. *Peromyscus maniculatus* apparently no longer occurs at or near the site.

Both species are common woodland forms in the state today. *P. leucopus* occurs everywhere except in the higher mountain summits. *P. maniculatus* is confined to cooler mountain forests above an elevation of 750 m (Handley & Patton, 1947).

It is possible that the percentage of *P. leucopus* to *P. maniculatus* increased in the cave area as the environment changed during the depositional history of the site, and that the 50/50 ratio of the identified material represents an average figure bridging a transition from predominantly *P. maniculatus* in late glacial times to 100% *P. leucopus* during the Holocene. Stratigraphic evidence from New Paris No. 4 suggests that this did occur in central Pennsylvania. In that fissure deposit, *P. maniculatus* formed 96% of the total *Peromyscus* recovered at the 8-10-m depth, but at the 0.25-m level was completely replaced by

Table 16. Measurements (in mm) *Peromyscus*, Clark's Cave. Late Pleistocene.

	$\bar{X}$	OR	SD	CV	N
		Length m1 – m3			
Peromyscus, ?species					
CM 24682	3.4	3.1–3.7	.14	4.20	48
		Length m1			
P. cf. *maniculatus*					
CM 29569	1.53	1.43–1.68	.05	3.26	41
P. cf. *leucopus*					
CM 29570	1.59	1.47–1.72	.06	3.86	37
above combined	1.56	1.43–1.72	.06	4.40	78
		Width m1			
P. cf. *maniculatus*					
CM 29569	.81	.71–.98	——	——	41
P. cf. *leucopus*					
CM 29570	.85	.67–.96	——	——	35
		Width m1 x 100 / Length m1			
P. cf. *maniculatus*					
CM 29569	52.5%	45.8%–61.2%	——	——	40
P. cf. *leucopus*					
CM 29570	53.5%	44.3%–62.5%	——	——	36

P. leucopus, the only species presently living at the site.

No evidence of golden mouse, *Ochrotomys nuttalli* (Harlan), or harvest mouse, *Reithrodontomys humilis* (Audubon and Bachman), small rodents with a dental morphology somewhat similar to *Peromyscus,* was noted. Both occur sparingly in western Virginia today on the northern edges of their ranges (Handley & Patton, 1947; Wilder & Fisher, 1972).

Neotoma floridana (Ord)—Woodrat

MATERIAL: CM 24536. 10 left, 12 right mandibles with at least m1 in place; 25 left, 39 right isolated m1's; 22 left, 34 right mandibles with no dentition; 1 skull; 3 palates; 21 left, 18 right maxillae. MNI = 51 individuals.

REMARKS: The woodrat is present at the site today. Five were trapped by C. O. Handley, Jr. and party in August, 1974. Woodrat droppings (15,000 estimated by weight) were the commonest organic items in the deposit, other than bones and teeth.

The woodrat is common in the southern and central Appalachians at all elevations, wherever suitable cliff/cave/talus habitat occurs. It does not range farther north than southern New York and western Connecticut (Hall & Kelson, 1959). Its failure to extend its range farther north in the Appalachians may be due to lack of suitable habitat rather than to climatic conditions *per se.* Other species of *Neotoma* occur in the mountains of western North America north to southern Alaska. Despite its modern temperate distribution, *Neotoma* was probably a member of the boreal late Pleistocene fauna at the site. *Neotoma* remains in association with boreal small mammals are known from New Paris sinkhole No. 4, Pa. *N. f. magister,* the northeastern race, probably occupied most of its present range, south of the glacial terminal moraine, throughout the Wisconsinan glaciation at least.

Measurements of Clark's Cave woodrat dentitions do not differ significantly from those of modern Pennsylvania comparative material (Table 17).

In *Neotoma,* occlusal area increases with tooth wear. Therefore comparisons can only be made between specimens of comparable age. The dentitions were ranked in three relative age classes: (1) light — wear pattern established on occlusal surfaces, but not yet fully developed; (2) medium — wear pattern fully developed, but reentrants not isolated by cingular wear; (3) heavy — at least some reentrants isolated by cingular wear. Occlusal length of molars in the first wear class is significantly shorter. These were calculated separately. In a sample of 68 m1's from Clark's Cave, 51% showed light wear, 44% showed medium wear, and 5% heavy wear.

Family: Arvicolidae—Voles (see Kretzoi, 1962)

Clethrionomys gapperi (Vigors)—Red-backed Vole

MATERIAL: CM 24519: 41 left, 27 right mandibles with m1; 3 left, 2 right m1's; 8 left, 7 right mandibles, no dentition; isolated upper molars. CM 24559: right m1 (Fig. 19K). CM 24560: right M3 (Fig. 19C). CM 24570: 84 left, 107 right mandibles with m1; 141 left, 168 right m1's; 154 left, 162 right M1's; 786 other molars. MNI = 305 individuals.

Table 17. Dental measurements (in mm) *Neotoma floridana (Ord).*

Locality	Toothwear	$\bar{X}$	OR	N
		Occlusal length m1 – m3		
Clark's Cave, Va.	Medium & heavy	9.8	9.3–10.2	5
Pennsylvania, Recent	Medium & heavy	9.7	9.5–10.2	15
		Occlusal length m1		
Clark's Cave, Va.	light	3.4	3.1–3.9	34
Clark's Cave, Va.	Medium & heavy	3.9	3.6–4.3	32
Pennsylvania, Recent	Medium & heavy	3.8	3.6–4.1	17
		Occlusal length m2		
Clark's Cave, Va.	Medium & heavy	3.2	3.0–3.4	14
Pennsylvania, Recent	Medium & heavy	3.3	3.1–3.6	17
		Occlusal length m3		
Clark's Cave, Va.	Medium & heavy	2.3	2.1–2.4	11
Pennsylvania, Recent	Medium & heavy	2.3	2.1–2.5	15

Specimens examined: Recent, Pa.: CM Mammal No's. 29170, 73, 74, 76, 77, 78, 79, 88; 32602, 04; 33545; 35078, 79, 82, 86, 89, 90; 38638, 41; 39337.

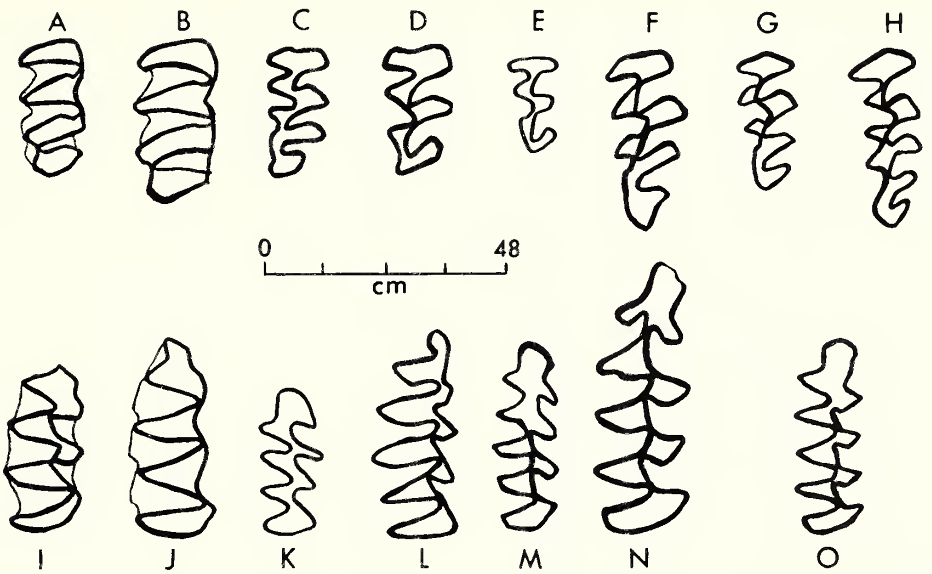

Fig. 19. Occlusal outlines of vole (Arvicolidae) molars, Clark's Cave local fauna, Bath County, Virginia. Cementum is indicated only for *Synaptomys*. UPPER ROW = right M3's: A. *Synaptomys cooperi*, CM 24566. B. *Synaptomys borealis*, CM 24564. C. *Clethrionomys gapperi*, CM 24560. D. *Phenacomys intermedius*, CM 24562. E. *Microtus pinetorum*, CM 24558. F. *Microtus xanthognathus*, CM 24553. G. *Microtus pennsylvanicus*, CM 24554. H. *Microtus chrotorrhinus*, CM 24555. LOWER ROW = right m1's. I. *Synaptomys cooperi*, CM 24565. J. *Synaptomys borealis*, CM 24563. K. *Clethrionomys gapperi*, CM 24559. L. *Phenacomys intermedius*, CM 24561. M. *Microtus pinetorum*, CM 24557. N. *Microtus xanthognathus*, CM 24552. O. *Microtus pennsylvanicus* or *chrotorrhinus*, CM 24556.

REMARKS: The red-backed vole is one of the commonest small mammals in the mountains of western Virginia. It is a forest vole of boreal affinity characteristic of northern coniferous forests of the Hudsonian and Canadian Life Zones and ranges south along the mountain summits of the Appalachians to northern Georgia. It does not occur at the site today despite the inviting appearance of the cool, shaded, cliff-based habitat. Extensive trapping in 1974 in and around the site failed to produce it. While it is common at higher elevations in the mountains, it is no longer present at the lower altitude of the Cowpasture River valley. Its presence in the deposit reflects former cooler woodland conditions near the site.

Red-backed voles accounted for 15% of the eight species of voles represented at Clark's Cave, 17% at Natural Chimneys, Va., and 21% at New Paris No. 4, Pa. No direct assessment of forest cover can be ascertained from such figures. At Sinkhole No. 4, Pa., within a vertical span of 4 m of continuous fissure fill, numbers of *Clethrionomys* increased from 4% at the lower level to 50% at the higher level. Correlated with this was a relative decline of field forms reflecting a period of floral change from open parkland to a closing coniferous forest. The vole assemblage, with the exception of *Dicrostonyx* at New Paris No. 4, is the same at all three sites—all dominated by *M. xanthognathus*. Unfortunately, the time span at Clark's Cave is not known, nor is any stratification apparent in the deposit itself, so that any internal changes in relative numbers of individual species could not be determined.

Clethrionomys remains were almost twice as common in the deposit as those of the woodland vole, *Microtus pinetorum* (MNI 305:170), the forest-inhabiting vole now present at the altitude of the site. This suggests that the boreal phase of the history of the site was the period of greatest depositional activity or duration. The sub-surface burrowing habits of *M. pinetorum* do not necessarily protect it differentially from predation. At a similar late Pleistocene owl roost, Natural Chimneys, Va., *M. pinetorum* was the more common of the two species

(MNI 47:65). *M. pinetorum* replaced the red-backed vole at lower altitudes in the central Appalachians as temperate conditions returned following the Wisconsinan glaciation. At New Paris, Pa., sinkholes No. 2 and No. 4 are located only a few meters apart. The *Clethrionomys*/*M. pinetorum* ratio changed from MNI 260:12 in the late Pleistocene boreal Sinkhole No. 4 fauna to MNI 0:51 in the Recent Sinkhole No. 2 assemblage.

In summary, *Clethrionomys* was a common species in the deposit, exceeded in MNI only by *M. xanthognathus*, *M. pennsylvanicus*, and *M. chrotorrhinus*, among the voles, and was almost twice as common as remains of *M. pinetorum*, the woodland vole now present at the site. This suggests that the boreal phase was the period of greatest depositional activity.

Phenacomys intermedius Merriam—Heather Vole

MATERIAL: CM 24515: 4 left, 5 right mandibles with m1; 1 left m1; 3 left, 1 right mandible, no dentition; 7 additional molars. CM 24561: right m1 (Fig. 19L). CM 24562: right M3 (Fig. 19D). CM 24571: 3 left mandibles with m1; 3 right mandibles with m1; 3 right mandibles, no dentition; 26 left, 12 right m1; 33 M1; 13 M2; 11 M3; 57 additional molars. MNI = 34.

REMARKS: This boreal rodent is no longer found in the eastern United States. It inhabits northern coniferous forest from the southern Yukon east to the Labrador coast. Unlike the northern bog lemming, *Synaptomys borealis*, which has a similar modern geographic distribution in eastern North America, *Phenacomys* does not occur south of the St. Lawrence estuary in the mountains of New Brunswick and northern New England.

Like the red-backed vole, *Clethrionomys*, the heather vole is not a grazer. Both genera, in contrast with all other American voles, have rooted molars, ill-suited for a diet of grasses. Heather vole remains at the site are, therefore, indicative of boreal forest of some type. Banfield (1974:193) summarizes its present habitat preferences, "Most have been taken in open, dry, coniferous forests of pine or spruce with an understory of heaths . . . usually near water . . . shrubby vegetation on the borders of forests and in moist, mossy meadows." It feeds on bark, buds, seeds and foliage of shrubs and forest understory.

Heather vole remains have been recovered from two other late Pleistocene cave sites in the state, Natural Chimneys and Back Creek No. 2. They were formerly widely distributed in late Pleistocene boreal faunas from periglacial eastern North America (Guilday & Parmalee, 1972).

Rarely taken by modern collectors, the heather vole is also rare in fossil collections: 3.6% of all voles at Natural Chimneys; 1.6% at Clark's Cave, and 3.8% at New Paris No. 4, Pa. It was the rarest vole in the Clark's Cave deposit.

Both boreal woodland forms, the relative abundance of *Phenacomys* and *Clethrionomys* remains in late Pleistocene sites from the central Appalachians are positively correlated: Clark's Cave, Va., 1.6% and 15%; Natural Chimneys, Va., 3.6% and 17%; New Paris No. 4, Pa., 3.8% and 21% of all voles respectively.

Microtus pennsylvanicus (Ord)—Meadow Vole

MATERIAL: CM 24521: 21 partial skulls plus maxillae and isolated molars for a total of 27 left M1, 31 right M1; 30 left M2; 26 right M2; 11 left M3, 7 right M3. CM 24554: right M3 (Fig. 19G). CM 24573: 138 left M1, 130 right M1; 262 left M2, 247 right M2; 294 left M3, 308 right M3. MNI = 316 individuals. Adjusted MNI = 658 individuals (69.3% of 950 *Microtus*, sp. m1's. See last paragraph of *M. chrotorrhinus* discussion for explanation of adjusted MNI).

REMARKS: The meadow vole is one of Virginia's commonest small mammals, occurring at all elevations in all meadow and grassy bog situations. The commonest species in the deposit, 24% of all terrestrial mammals, it is also the most widely distributed small vole in North America today. A closely related form, *M. agrestris*, the field vole, occurs widely in Europe and northern Asia as well. The two populations are now widely separated geographically but are obviously derived from a common stock (Klimkiewicz, 1970). Although the meadow vole occurred as far south as Florida during late Wisconsinan times (Devil's Den, Martin, 1974b) it does not occur in the southeastern lowlands today. It ranges from South Carolina and the highlands of Georgia to northern Labrador, including all of Canada south of the tundra, west to the coast of Alaska. Modern barn owl pellets from the Clark's Cave cliffs yielded meadow vole remains, and they were trapped in the Cowpasture River valley by C. O. Handley, Jr., and party in 1974.

The abundance of *M. pennsylvanicus* remains in the deposit reflects not only the presence of suitable meadowlands in the river valley and the field-hunting predilections of the owls, but the fact that this was the only rodent in the deposit that was probably taken in undiminished numbers throughout its depositional history. It would have been the species least affected by the climatic change from the boreal late Pleistocene period to modern temperate in the central Appalachians. As long as moist grassy areas were present, so was this vole.

Microtus pennsylvanicus was also the commonest species of terrestrial mammal recovered from both Natural Chimneys, Va., and New Paris No. 4, Pa. At only one site analyzed to date was it relatively uncommon: the Recent New Paris No. 2, Pa. (3 *M. pennsylvanicus*, 51 *M. pinetorum*). This is because animals trapped in New Paris No. 2 were only those whose immediate home ranges included the sinkhole entrance into which they tumbled. Had the deposit been an old owl roost accumulation like that at Clark's Cave, *Microtus pennsylvanicus* would have been present in large numbers concentrated by meadow-foraging owls. The dry woodland surrounding the mouth of New Paris No. 2 does not support *M. pennsylvanicus* even though it is regionally common.

Dentitions of this species from central Appalachian fossil deposits, as well as those of *M. xanthognathus* and *M. chrotorrhinus*, agree in having a lower first molar exhibiting a pattern of five closed triangles between the posterior crescent and the anterior trefoil (ml of *M. pinetorum* has three closed triangles, the fourth and fifth being broadly confluent). This advanced eondition and their abundance in such sites makes them convenient horizon-markers. *Microtus* molars with five triangles are not present in earlier Pleistocene deposits, e.g., those at Cumberland Cave, Md. (late Kansan), and Trout Cave, W. Va. (Kansan/Yarmouthian). Instead, ml's of a simpler evolutionary grade, possessing three to four triangles, are present (van der Meulen, unpublished).

Microtus chrotorrhinus (Miller)—Rock Vole

MATERIAL: CM 24520: left maxilla with M1-M3; partial skull with left M1-M2, right M2-M3; 3 M3. CM 24555: right M3 (Fig. 19H). CM 24574: 3 left, 3 right M1; 3 left, 6 right M2; 102 left, 135 right M3. MNI = 140 individuals. Adjusted MNI = 292 individuals (30.7% of 950 *Microtus*, sp. ml, see last paragraph, this discussion.

REMARKS: The rock vole has never been trapped in Virginia but may possibly occur on some of the higher mountain summits. This animal has one of the most aberrant habitats of any North American *Microtus*. During the boreal episode of late Wisconsinan times the rock vole enjoyed a much wider geographical distribution in eastern North America. But following the retreat of the Wiseonsinan ice sheet, its range in the central and southern Appalachians has been reduced to small disjunct populations in rocky areas of cool mountain forests above 900 m. Its continued presence in the southern and central Appalachians is due solely to the persistence of such ecological enclaves, but it is absent in most of them now. Post-Wisconsinan range adjustment of *M. chrotorrhinus* consisted of local extinction and retreat to higher altitudes in the southern portions of its range, coupled with colonization of suitable northern areas as coniferous forest advanced into recently ice-freed areas. There were apparently few or no adaptive changes on the part of the animal itself. R. L. Martin (1973), in a detailed study of 464 Recent specimens from over 55 localities from Labrador to North Carolina, found no indication of clinal variation in the dentition. He did find a random pattern of variation from site to site caused by restricted gene flow between widely scattered populations marooned, as it were, on boreal "islands" in the eastern deciduous forests. The late Pleistocene sample of cranial material and dentitions from New Paris No. 4, Pa., is indistinguishable from *M. chrotorrhinus* in every character studied by Martin, but it averages somewhat larger in length of toothrow than modern central Appalachian material. Unfortunately, the *M. chrotorrhinus* sample from Clark's Cave was too fragmentary for measurement of other than isolated teeth.

The ratio of *M. chrotorrhinus* to *M. pennsylvanicus* varies from 4.8% at Natural Chimneys, Va., and 21.5% at New Paris No. 4, Pa., to a high of 30.7% at Clark's Cave. These varying percentages probably reflect the regional extent of rocky habitat favored by this species. The talus fronting the high Clark's Cave cliffs appears most favorable for this vole. Extensive trapping by C. O. Handley, Jr. and party in 1974, however, proves that *M. chrotorrhinus* no longer occurs at the site, despite the presence of cool, damp, forested, rocky tumbles. During a cooler episode, however, it would have made ideal habitat, providing a ready supply of rock voles for predators.

The identification and assessment of minimum numbers of individuals of all voles from the deposit, with the exception of *M. chrotorrhinus* and *M. pennsylvanicus*, was based upon counts of ml's. The largest and most readily identifiable tooth in vole dentitions, the ml has a greater percentage of recovery in the field, because of its larger size, than do the other relatively smaller molars. Unfortunately the ml's of *M. chrotorrhinus* and *M. pennsylvanicus* look alike, and minimum numbers of individuals of these two species had to be based upon the smaller but distinctive M3's. The combined total of these two species, based upon the more easily lost M3's was 456. However, a census of all *Microtus* ml's that could be referred to either species came to a minimum of 950 individual animals, indicating a considerable loss in recovery of the smaller M3's. If this were the case, then minimum numbers of *M. chrotorrhinus* and *M. pennsylvanicus* could not be legitimately compared to minimum numbers of the other species of voles from the site. To remedy this, an adjusted minimum number of individuals for these two species was obtained by dividing the 950 MNI, based on m1's, by the relative percentages of *M. chrotorrhinus* to *M. pennsylvanicus* as indicated by M3 counts. This was also done at New Paris No. 4, Pa. (*M. pennsylvanicus* = 361, or 78.5% of *Microtus* sp.; *M. chrotorrhinus* = 99, or 21.5% of *Microtus* sp.), and Natural Chimneys, Va. (*M. pennsylvanicus* = 121, or 95.2% of *Microtus* sp.; *M chrotorrhinus* = 6, or 4.8% of *Microtus* sp.). Some isolated M3's are of intermediate morphology and perhaps 5% were misidentified. But the chances of misidentification are reciprocal and this source of error probably does not influence the relative ratios of *M. chrotorrhinus* to *M. pennsylvanicus* based upon M3's from the site.

Microtus xanthognathus (Leach)—Yellow-cheeked Vole

MATERIAL: CM 24522: 156 left, 194 right mandibles with m1; 21 left m1, 14 right m1; 5 left m3, 16 right m3; 79 partial skulls, 7 maxillae with 42 left M1, 42 right M1, 18 left M2, 25 right M2, 8 left M3, 10 right M3. CM 24552: 1 right m1 (Fig. 19N). CM 24553: 1 right M3 (Fig. 19F). CM 24572: 33 left, 42 right mandibles with m1; 288 left m1, 260 right m1, 110 left M1, 97 right M1, 31 left M2, 42 right M2, 182 left M3, 205 right M3; 4 partial skulls. MNI = 511 individuals.

REMARKS: The largest species of North American *Microtus* with an average weight three times that of *M. pennsylvanicus*, the yellow-cheeked vole was the single most important food item in the deposit. It was exceeded in numbers of individuals only by the meadow vole. Both species outnumbered all other terrestrial small mammals.

Despite its abundance, no other mammal in the deposit has adjusted its range so dramatically from that day to this. Remains of this vole have been recovered south of the late Wisconsinan ice moraines from late Pleistoeene sites in Missouri, Iowa, Illinois, Kentucky, Pennsylvania, West Virginia, Virginia, and Tennessee. Its range has now shifted north almost 20° in latitude, some 1,900 km, to the taiga of western Canada and Alaska, where it is now rare, local, and seldom collected.

The yellow-cheeked vole was also a dominant small mammal at New Paris No. 4, Pa. (344 MNI). As at Clark's Cave, it was slightly exceeded in numbers by *M. pennsylvanicus* (361 est. MNI). When large numbers of *M. xanthognathus* were encountered at New Paris No. 4, Pa., there was some question about whether this species, so rare and local today, was present in such relatively large numbers regionally, or whether ecological conditions immediately surrounding the sinkhole mouth produced a local condition favorable to *M. xanthognathus*, creating a "hot spot" which did not reflect the regional picture. Its abundance at Clark's Cave, however, clarifies its regional signifieance. Instead of tumbling into a sink trap, the Clark's Cave *M. xanthognathus* were concentrated from a much larger area. They must have been abundant in the cruising range of the Clark's Cave raptors, sustaining their numbers over a long period of time, to bulk so large in the deposit.

Despite the different accumulation mechanisms at New Paris No. 4, Pa., and Clark's Cave, Va., and the fact that they are 240 km apart, both sites are located just east of the Appalaehian Plateau in the now relatively dry intermontane valleys of the Ridge and Valley section of the Appalachians. Dry shale barrens are characteristic of both areas today, and the general character of the two sites, allowing for the difference in latitude, may have been similar during late Pleistocene times. The only other Virginia localities for fossil *M. xanthognathus*, Natural Chimneys and Back Creek No. 2, are also in the mountainous western portion of the state. This is probably a reflection of differential distribution of suitable fossil traps. Remains from Bootlegger Sink, Pa. *(M. xanthognathus)*, and Little Kettle Creek, Ga. (*Clethrionomys, Synaptomys*, Voorhies, 1974), indicate that boreal small mammals were widely distributed in the eastern Piedmont south and east of their present ranges. The former widespread occurrence of *M. xanthognathus* in the American Midlands (Hallberg, Semken, and Davis, 1974) and its relative abundance in such sites strongly suggests that this now-rare vole was both widespread and common in eastern North America south of the continental Wisconsinan glaciation—a eonvenient index fossil for deposits of this age. It appears, however, not to have been present in western North America during this time. It has not been reported from numerous sites of comparable age in the central Rockies (Jaguar Cave, Ida.; Wilson Butte, Ida.; Little Box Elder Cave, Wyo.). Even today the animal is not found in mountainous terrain. It has not been reported from sites older than Wisconsinan. It was not present in the Appalachians in Kansan/Yarmouthian times (Cumberland Cave, Md.; Trout Cave, W. Va.) and the pre-Wisconsinan history of this species is unknown.

Unfortunately, this vole is so seldom collected and occurs so sporadically throughout its range, that habitat information of the living animal is sketchy and general. It occurs, randomly and unpredictably, in a variety of boreal woodland situations. Its range is included in the Hudsonian Biotic Province of Dice (Dice, 1943), the taiga, avoiding both barren-ground habitat to the north and the closed coniferous forests of the Canadian Biotic Province of southern Canada. In the taiga, however, it has been found in both moist valley sites and upland well-drained woodlands. It burrows extensively, appears to prefer friable soils, although it may occur in wet sphagnum bogs. It does not oecur in grasslands, like *M. pennsylvanicus*, or in rocky wooded talus as does *M. chrotorrhinus*. All accounts of present habitat (Preble, 1908; Lensink, 1954; Banfield, 1974; Youngman, 1975) mention some form of woodland cover—a thin boreal forest dominated by spruce and jackpine with a ground covering of heaths and sphagnum would accommodate this vole.

Although *M. xanthognathus* and *M. chrotorrhinus* are both boreal forest forms, with sympatric ranges in the mid-Appalachians during at least Wisconsinan times, their ranges are widely separated today. *M. xanthognathus* occurs in the western sub-Arctic, its known range separated from that of *M. chrotorrhinus* by approximately 800 km. *M. chrotorrhinus* is found only in the eastern sub-Arctic and as a relict form south in the higher Appalachians. Why have these two species gone their separate ways (Fig. 20)?

The following sketch agrees with the paleontological and geological facts, as far as they are known, and may explain the present distribution of these two species. Both species have been recovered from seven late Pleistocene sites (New Paris No. 4, Pa.; Bootlegger Sink, Pa.; Eagle Rock, W. Va.; Back Creek No. 2, Va.; Natural Chimneys, Va.; Clark's

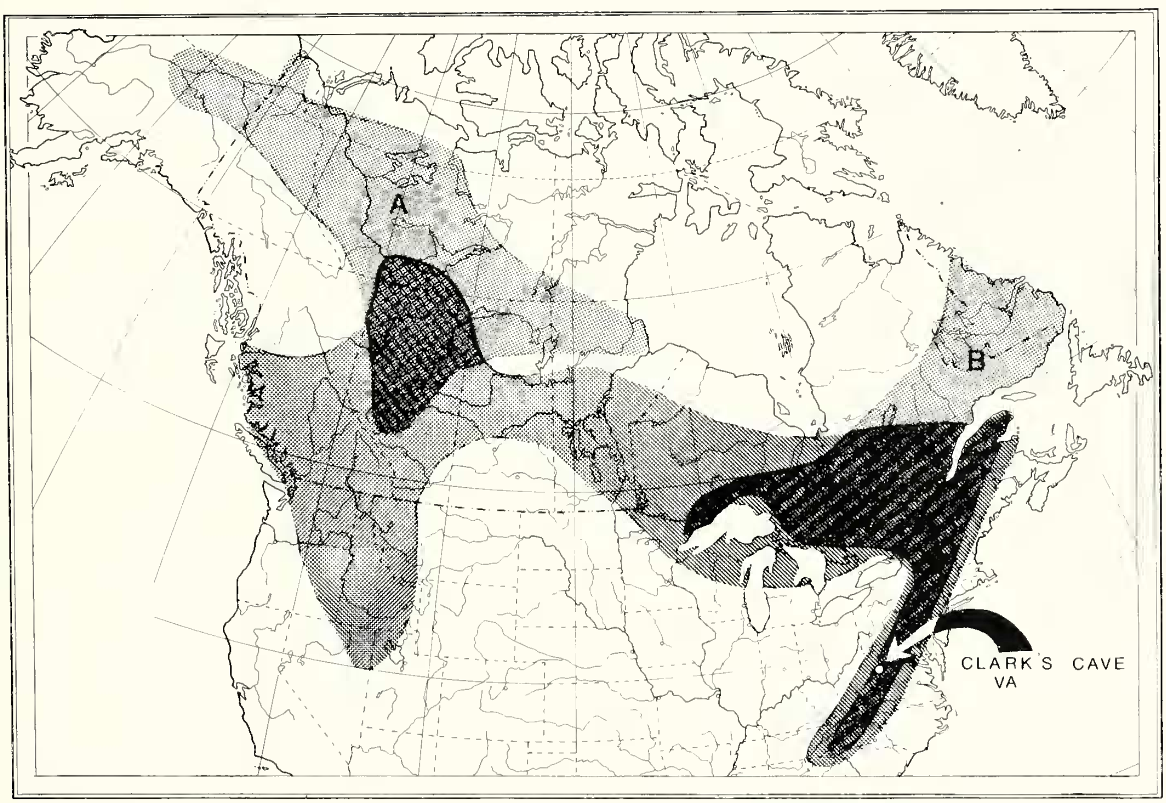

Fig. 20. Modern ranges of (A) Yellow-cheeked vole, *Microtus xanthognathus* (Leach); (B) Rock vole, *Microtus chrotorrhinus* (Miller); superimposed upon Canadian Life Zone; from Hall & Kelson, 1959. Appalachian portion of Life Zone highly generalized from true fragmented situation.

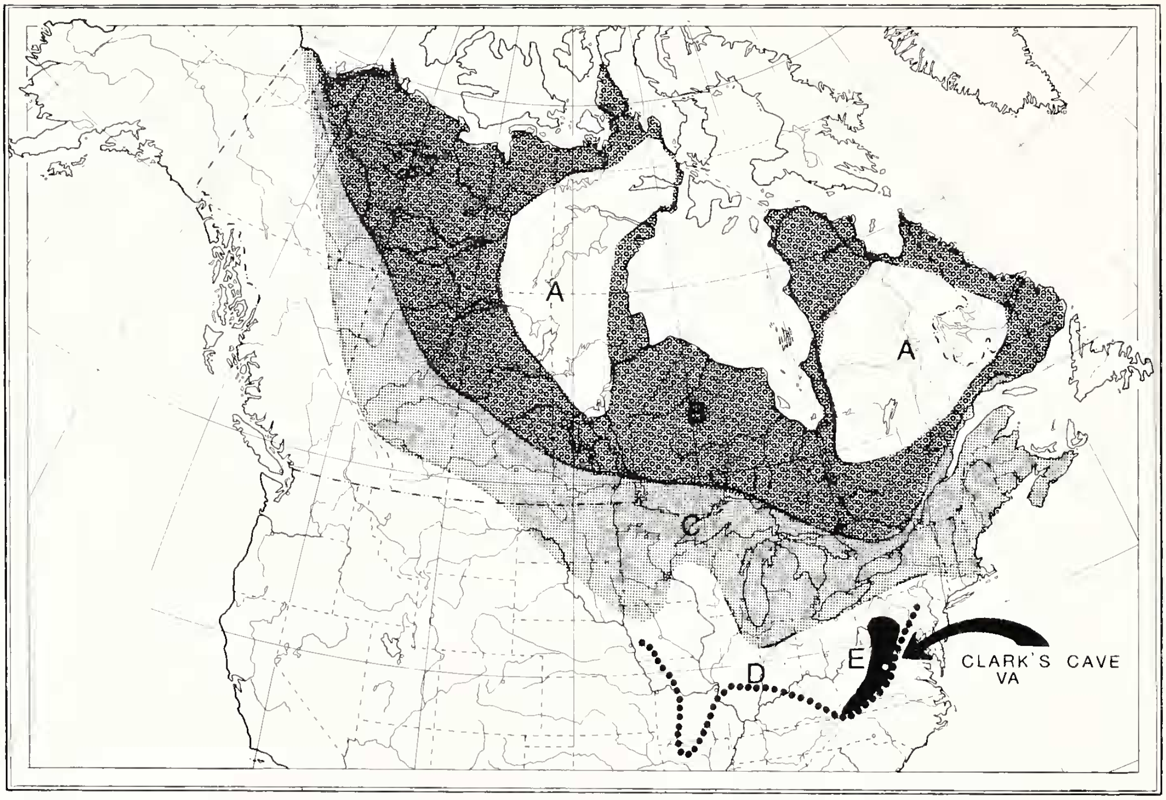

Fig. 21. Successive stages of continental Wisconsinan glacial recession in central and eastern North America (from Bryson *et al.*, 1969), and periglacial ranges of yellow-cheeked vole, *Microtus xanthognathus* (Leach), (from Hallberg *et al.*, 1974) and rock vole, *Microtus chrotorrhinus* (Miller). A = ice cover, 7,000 years B.P. B = ice cover, 9,000 years B.P. C = ice cover, 12,000 - 13,000 years B.P. D = Wisconsinan periglacial range of *Microtus xanthognathus* (Leach). E = Wisconsinan periglacial range overlap, *M. xanthognathus*, *M. chrotorrhinus*.

Cave, Va.; and Baker Bluff, Tenn.) but all these sites are in or near the Appalachian Mountains. Sites farther west (Welsh Cave, Ky.; Meyer Cave, Ill.; Waubonsie local fauna, Iowa; Bat Cave, Mo.; Peccary Cave, Ark.) have produced remains of *M. xanthognathus* only (Fig. 21).

As post-glacial warming set in and the open boreal forest of periglacial central and eastern North America gave way to denser tree cover and more temperate conditions, *M. chrotorrhinus* was able to survive in the Appalachians by retreating to higher elevations. Its range fragmented in the central and southern Appalachians as suitable rocky boreal habitat became increasingly restricted. Density of tree cover apparently had little effect as long as the animal could resort to its preferred habitat. *M. xanthognathus*, however, became extinct in the Appalachians, as post-glacial reforestation produced a closed-canopy forest.

Continental meltback of the Wisconsinan ice front proceeded much more rapidly in the American Midlands than it did in the East (Fig. 21). Continental ice masses persisted in both Ungava and eastern Keewatin for thousands of years after an ice-free corridor in the Central Plains opened east of the Rocky Mountains north to Alaska. As this corridor opened to the Northwest, it was colonized by *M. xanthognathus* from the south. The animal's range shifted to the north *in toto*, advancing on its northern front, becoming extinct in its southern fringes as reforestation eclipsed its preferred habitat in that area. Unable to spread northeast into the eastern Arctic at this time because of the persistent ice block, or to continue in relict habitats in the Appalachians, as did *M. chrotorrhinus*, it could only follow the fortunes of the taiga as it retreated (or advanced?) to higher latitudes in the Northwest. When the eastern ice block melted, sometime after 7,000 years B.P. (Bryson *et al.*, 1969), eastern Keewatin, south of the barren ground, was duly colonized by *M. xanthognathus*. Access farther east to Ungava was blocked by Hudson Bay and by closed boreal forests to the south. By the time Ungava was open to biotic invasion from the south, *M. xanthognathus* was extinct in the Appalachians. Hudson Bay has also acted as a barrier to the eastern post-glacial spread of the lemming *Dicrostonyx torquatus*, allowing the isolated *D. hudsonius* to survive in the tundra of Ungava (Guilday, 1963).

Microtus pinetorum (LeConte)—Woodland Vole

MATERIAL: CM 24524: 3 left, 4 right mandibles with m1; 7 left, 5 right m1. CM 24557: 1 right m1 (Fig. 19M). CM 24558: 1 right M3 (Fig. 19E). CM 24576: 24 left, 18 right mandibles with m1; 136 left, 114 right m1; 31 left, 33 right M3. MNI = 170 individuals.

REMARKS: The woodland vole, 8% of all voles in the deposit, was the least common of the four identified species of *Microtus* (Table 4). Although only *M. pennsylvanicus* was trapped in the area by C. O. Handley, Jr. and party in 1974, and present in a few barn owl pellets from the cliffs, *M. pinetorum* is undoubtedly present in the Cowpasture River valley wherever conditions are suitable for this semi-burrower. It is present throughout western Virginia at medium-to-low altitudes, in loose, friable soils of open woodlands, orchards, and field borders.

Identification to species is based upon geographic probability. It is conceivable that *M. ochrogaster* may be represented as well.

The woodland vole does not occur in the northern coniferous forests, reaching its northern limits at approximately the U.S./Canadian border. It is present in all late Pleistocene sites examined to date from the mid-Appalachians, and probably was present during the boreal episode of deposition.

It is replaced at higher elevations in the Appalachians today by the red-backed vole, *Clethrionomys gapperi*, another woodland form. At New Paris No. 4, Pa. (11,300 years B.P.), 260 *Clethrionomys*, but only 12 *M. pinetorum* (4.4% of their combined number) were recovered. At Clark's Cave, ratio of *M. pinetorum* to *C. gapperi* is 36%. This large relative increase at Clark's Cave may be due either to the presence of *M. pinetorum* in larger numbers during the boreal episode, or to deposition at Clark's Cave continuing on into more temperate times. We suspect the former. The occurrence of macrofossils of deciduous trees and shrubs (*Quercus, Corylus*) in a predominantly boreal spruce (*Picea*) flora and the apparent association of *Phenacomys, Clethrionomys, M. pennsylvanicus,* and *M. pinetorum* in alluvial silts of the Brayton local fauna of southwestern Iowa (Dulian, MS), dated at 12,420+ 180 years B.P., a time near the final retreat of the Wisconsinan ice from Iowa, suggests that *M. pinetorum* may also have been at Clark's Cave during the boreal episode of deposition.

Ondatra zibethicus (Linnaeus)—Muskrat

MATERIAL: CM 24526. Partial palate with left m1-m2; 4 left, 3 right mandibles with m1; 2 right mandibles, no dentition. MNI = 5 individuals.

REMARKS: This is an abundant semi-aquatic species present at the site today and throughout most of temperate and boreal North America south of the tundra. The low number of muskrats from this riverbank site can be accounted for by their relatively large size and aquatic habits, protecting them from owl predation.

Synaptomys cooperi Baird—Southern Bog Lemming

MATERIAL: CM 24517: 1 right mandible with m1; 1 right mandible, no dentition; 1 left m1; 1 right m3. CM 24565: 1 right m1 (Fig. 19I). CM 24566: 1 right M3 (Fig. 19A). CM 24567: 2 right mandibles with m1; 22 left m1's, 18 right m1's. MNI = 23 individuals.

REMARKS: The southern bog lemming is relatively widespread in meadows, dry fields, and occasional bogs in western Virginia, at all altitudes (Handley & Patton, 1947:169). It is the rarest vole in the area. In the Appalachian Mountain region its range extends from the Great Smoky Mountains in the south, north through New Brunswick to southern Labrador. In the northern portions of its range *S. cooperi* is narrowly sympatric with the southern fringe of the range of the northern bog lemming, *S. borealis.* Although *S. cooperi* is more temperate in distribution, the ecological differences between the two species in their area of sympatry are not clear.

Both species were recovered from New Paris. No. 4, Pa., where a stratigraphic shift in relative numbers made it apparent that *S. cooperi* gradually replaced *S. borealis* in the central Appalachians somewhere near 11,000 years B.P. as the climate ameliorated. *S. cooperi* accounted for 20% of all *Synaptomys* recovered at New Paris No. 4, Pa. At Clark's Cave the proportion of *S. cooperi* was somewhat greater, 27% of all *Synaptomys* (N = 84). This may reflect either a difference in the relative ages of the sites, an ecological difference caused by differing physical parameters, or a reflection of a longer period of deposition at Clark's Cave, extending into temperate times.

The *S. cooperi* remains from Clark's Cave agree in size with those from other late Pleistocene deposits in the central Appalachians (Table 18), smaller than the population now in the area. This probably reflects a cold-stressed environment and it mirrors the present size cline of modern *S. cooperi*, i.e., an inverse size/latitude correlation. This, together with a relatively low coefficient of variation, suggesting a common gene pool, indicates that the *S. cooperi* remains at Clark's Cave were largely laid down prior to the advent of full-temperate conditions at the site.

Synaptomys borealis (Richardson)— Northern Bog Lemming

MATERIAL: CM 24516: 7 left, 4 right mandibles with m1; 3 left, 5 right m1; 1 right m2; 1 left, 1 right m3. CM 24563: 1 right m1 (Fig. 19J). CM 24564: 1 right M3 (Fig. 19B). CM 24568: 4 left, 8 right mandibles with m1; 40 left, 43 right m1; 1 left, 1 right M1. MNI = 61 individuals.

REMARKS: This forest lemming is no longer found in the central or southern Appalachians. Its present range includes the boreal forest and taiga from Alaska to Labrador, south to Minnesota and the White Mountains of New Hampshire, 1,000 km northeast of Clark's Cave. Its habitat is variously described (Soper, 1942, 1948; Banfield, 1974) as ranging from moist to dry situations—grassy, second-growth spruce and poplar; thick gloomy spruce woods carpeted with sphagnum; grass-clumped willow swamp; small meadows; moist spruce woods; spruce bogs; alpine meadows.

Uncommon to rare throughout its range today, the northern bog lemming is commonly found in late Pleistocene deposits from the central Appalachians (New Paris No. 4, Pa.; Bootlegger Sink, Pa.; Eagle Cave, W. Va.; Bowden Cave, W. Va.; Natural Chimneys, Va.; Back Creek Cave No. 2, Va.; Guy Wilson Cave, Tenn.; Baker Bluff Cave, Tenn.; Robinson Cave Tenn.). Its remains are never present in large numbers, however. At New Paris No. 4 (MNI 71) it comprised only 5.8% of all voles recovered, at Clark's Cave (MNI 61) only 3% of all voles.

Occlusal length of 33 m1 from Clark's Cave, Va., averaged 2.88 mm, OR 2.5-3.2 mm, SD .04, CV 1.39. Eighty m1 from New Paris No. 4, Pa., averaged 2.91 mm, OR 2.3-3.2, SD .17, CV 5.84.

Family: Zapodidae—Jumping Mice

Zapus hudsonius (Zimmerman)— Meadow Jumping Mouse

MATERIAL: CM 29572: 29 mandibles, with at least m1; 12 additional m1; 12 m2; 28 maxillae. MNI = 22 individuals.

REMARKS: The meadow jumping mouse is broadly distributed throughout northern North America, south of permafrost, from southern Alaska east to Labrador, south to Oklahoma, Alabama, and Georgia (Hall & Kelson, 1959:772). It prefers meadow and old-field situations of dense low vegetation, stream banks, and clearings in either open or forested country. *Zapus* is present at the site today; one was trapped in the hay fields above the cave in August, 1974, by C. O. Handley, Jr. It is present throughout the state wherever there is suitable habitat (Handley & Patton, 1947:182). Measurements of 36 lower first molars are: Total length, M = 1.5 mm; OR = 1.38 mm—1.70 mm. Measurements of 22 M2's are: Total length, M = 1.39 mm; OR = 1.26—1.57 mm.

Napaeozapus insignis (Miller)— Woodland Jumping Mouse

MATERIAL: CM 29573: 15 mandibles with m1; 13 additional m1; 17 m2; 13 maxillae. MNI = 15 individuals.

REMARKS: The woodland jumping mouse does not occur at Clark's Cave today. It is closely confined to stream banks and woodland edge situations in the spruce/fir and hemlock/northern hardwood forests of eastern North Ameriea, from the Lake Superior region east to southern Labrador, thence south along the Appalachian Mountains at increasing altitudes to northern Georgia (Wrigley, 1972). In Virginia it is confined to mountain summit forests of cool, moist, rocky aspect in the western part of the state at higher elevations (Handley & Patton, 1947). *Napaeozapus insignis* exhibits a pronounced "Bergmann's Response." Individuals from the extreme southern portions of its range average some 12% smaller than those of eastern Canada (Wrigley, 1972). Specimens from the Clark's Cave deposit have greater dental dimensions than modern mid-

Table 18. Measurements (in mm) *Synaptomys cooperi* Baird, occlusal length m1.

Locality	$\bar{X}$	OR	SD	CV	N
Pennsylvania, Recent[1]	2.48	2.1–2.7	0.19	7.66	25
New Paris No. 4, Pa., late Pleistocene[1]	2.41	2.3–2.5	0.09	3.73	20
Clark's Cave, Va., late Pleistocene	2.40	2.2–2.7	0.11	4.75	33
Natural Chimneys, Va., late Pleistocene[1]	2.39	2.2–2.5	0.05	2.92	14

[1]Data from Guilday, *et al.*, 1964: 162.

Table 19. Dental measurements (in mm) *Napaeozapus insignis* (Miller).

Age and locality	$\bar{X}$	OR	N
	Total length m1		
Recent:			
Pennsylvania[1]	1.6	1.5–1.8	20
Late Pleistocene:			
New Paris No. 4, Pa.[1]	1.8	1.7–2.1	11
Natural Chimneys, Va.[1]	1.7	1.6–1.7	6
Clark's Cave, Va.	1.7	1.6–1.9	27
	Total length m2		
Late Pleistocene:			
Clark's Cave, Va.	1.6	1.5–1.8	21

[1]Measurements from Guilday *et al.*, 1964: 168.

Appalachian material by some 7%. They compare most closely with late Pleistocene specimens from New Paris No. 4, Pa., and Natural Chimneys, Va. All three sites agree in the boreal nature of their respective faunas. The *Napaeozapus* from all three sites represent a late Pleistocene population in the mid-Appalachians, larger than the population now present in the area.

Family: Erethizontidae—Porcupines

Erethizon dorsatum (Linnaeus)—Porcupine

MATERIAL: CM 24528: 1 left mandible with full dentition; 2 upper molars. MNI = 1 individual.

REMARKS: There are no modern records for the porcupine in Virginia. It reaches its present southern limits as a breeding population in northern Pennsylvania (Doutt *et al.*, 1973). Porcupine remains have been recovered from Natural Chimneys, Va. It was apparently more widespread in karst areas immediately west of the Appalachians where it has been reported from Late Prehistoric archaeological sites as far south as Tennessee and Alabama (Parmalee & Guilday, 1966; Barkalow, 1961; Weigel, 1974). Primarily a denizen of coniferous, or northern hardwood, forests, the porcupine is also strongly attracted to rocky terrain and caves.

Family: Canidae

Canis, cf. *C. dirus* Leidy—Dire Wolf

MATERIAL: CM 29611: 1 right unciform. MNI = 1 individual.

REMARKS: Large mammal remains are rare in the deposit. The single carpal is 20% larger than a comparable unciform of a large male timber wolf, *C. lupus* from Alaska (CM mammal no. DC 1247). It is referred with confidence to the dire wolf because of its size and the late Pleistocene age of the bulk of the collection.

The dire wolf is the only species of wolf present in Appalachian deposits of Wisconsinan age. It was replaced by the timber wolf following its extinction at the close of the Pleistocene.

Direct comparison was made with the Clark's Cave unciform and the adjacent carpal, an os magnum, of the Powder Mill Creek Cave, Mo., *C. dirus* skeleton (Catalog No. P-249, Galbreath, 1964). They were of comparable size.

Measurements of CM 29611 are: greatest depth, 22.2 mm; length metatarsal IV facet, 17.4 mm, approx.; width metatarsal IV facet, 17.1+ mm. (*C. lupus* DC 1247 = 17.5 mm, 13.1 mm, 15.0 mm, respectively).

Family: Ursidae

Ursus americanus Pallas—Black Bear

MATERIAL: CM 24592: 1 m2. CM 29696: 1 phalanx. MNI = 1 individual.

REMARKS: Definitely not a raptor prey item, the isolated tooth and phalanx were probably deposited by hoarding woodrats. Measurements of the m2 are: length of crown, 15.5 mm; width of crown, 10.7 mm. This agrees well with measurements of 17 sixteenth-through-seventeenth-century archaeological specimens from two late prehistoric sites in West Virginia (46 Pu 31 and 46 Fa 7): length 15.3 mm (13.1-17.7 mm), width 11.8 mm (10.7-13.3 mm). The black bear is still found in the mid-Appalachians.

Family: Procyonidae

Procyon lotor (Linnaeus)—Raccoon

MATERIAL: CM 24593: 1 right upper deciduous molar. MNI = 1 individual.

REMARKS: Adults are too large for the majority of raptors. The juvenile represented by this single molar may have been owl prey.

Family: Mustelidae

Martes americana (Turton)—Pine Marten

MATERIAL: CM 24954: distal half right humerus; distal half right tibia. MNI = 1 individual.

REMARKS: There is no evidence that the pine marten was ever found in Virginia during historic times. It did occur as far south as Pennsylvania in northern coniferous/hardwood forests (Rhoads, 1903). Paradiso, 1969, believes it to have been exterminated in the mountains of Maryland, "as far back as 85 years ago," and it once may have occurred in the ridgetop spruce forests of West Virginia. It is a common late Pleistocene cave fossil from the mid-Appalachians and has been reported from Eagle Cave, W. Va., Benedict's Cave, W. Va. (CM 24698), New Paris No. 4, Pa., Natural Chimneys, Va., and as far south as Robinson Cave in central Tennessee.

Genus *Mustela* Linnaeus

Mustela erminea Linnaeus—Ermine

MATERIAL: CM 24597: 1 left, 2 right maxillae with P4; 1 left, 2 right P4; 3 left, 2 right mandibles with m1; 1 right mandible, no dentition; left humerus, left femur, left tibia. MNI = 4 individuals.

Mustela nivalis Linnaeus—Least Weasel

MATERIAL: CM 24596: 6 left, 2 right P4; partial skull with P4; 3 left, 2 right mandibles with m1; 1 left, 1 right m1; 1 humerus. MNI = 7 individuals.

Mustela ?species, cf. *M. frenata* (female) or *M. erminea* (male)

MATERIAL: 29699: anterior half of skull with left P4-M1, right P2, right P4-M1. MNI = 1 individual.

Mustela vison Peale & Palisot de Beauvois—Mink

MATERIAL: CM 24595: partial skull; left mandible fragment; right humerus; 2 right femora; right tibia. MNI = 2 individuals.

REMARKS: The relative scarcity of carnivores in the deposit reflects the collecting bias of the birds of prey. Large species were either not represented at all, or by isolated teeth of fortuitous occurrence. A few small carnivores did find their way into the deposit as prey items, their numbers in inverse proportion to their size. The two weasels definitely present in the deposit, *M. erminea* and *M. nivalis*, are the two smallest North American carnivores.

The least weasel is rare in the state today but is probably present throughout the mountain counties of the state (Handley & Patton, 1947). It is a circumboreal species whose range extends along the Appalachian Mountains south to the Great Smokies. *M. erminea* has not been recorded, either living or fossil, as far south as Virginia. It, too, is a circumboreal species, but reaches its present southern limits in northern Pennsylvania, where it is uncommon. There is one anomalous record from the Piedmont of Maryland (Vazquez, 1956).

Late Pleistocene remains of least weasel have been recovered from New Paris No. 4, Pa., Natural Chimneys, Va., and Back Creek No. 2, Va., in the central Appalachians, and west of the Appalachians, from Meyer Cave, Ill., Welsh Cave, Ky., and Robinson Cave, Tenn. *M. erminea*, however, has not previously been reported from the Pleistocene of eastern periglacial North America. It was present in the Conard Fissure, Ark., far south of its modern range (Brown, 1908).

M. frenata, the long-tailed weasel, the commonest species in Virginia today, is not definitely represented in the deposit. The possible partial skull listed above is not complete enough for identification. At least three *M. frenata* specimens were recovered from Natural Chimneys, Va., and the species was undoubtedly present in the Clark's Cave area at some period during the accumulation of the deposit.

Although the presence of *M. erminea* points to more boreal conditions in the area at one time, all weasels and mink occur in such a variety of ecological conditions throughout their range that they provide no definite paleoecological clues.

cf. *Mephitis mephitis* (Schreber)—Striped Skunk

MATERIAL: CM 24598: 1 ulna; 1 left, 1 right lower canine. 1 basicranial fragment.

REMARKS: The elements are too large for spotted skunk, *Spilogale*, and the identification is tentative because of the fragmentary nature of the specimens. The presence of the hooded skunk, *M. macroura*, or the hognosed skunk, *Conepatus* (Ladds Quarry, Ga.), in such a boreal deposit seems remote.

Family: Cervidae—Deer

cf. *Cervus elaphus* Erxleben—Elk

MATERIAL: CM 29697: posterior zygopophyses of an anterior lumbar vertebra.

cf. *Odocoilus virginianus* Zimmerman—White-tailed Deer

MATERIAL: CM 29698: left naviculocuboid. 2 thoracic spines, 1 partial third or fourth cervical vertebra.

REMARKS: Identifications are tentative, based upon size comparisons with Recent material. These fragments may have been introduced by Recent woodrat activities, although signs of extensive gnawing were not noted. White-tailed deer are common in the area today. Both elk and deer remains have been reported from prehistoric Indian sites in Bath County approximately 11 km west of the cave (MacCord, 1973a, 1973b).

Caribou (*Rangifer tarandus*) are known to have inhabited the Ridge and Valley section of the Appalachians as far south as Tennessee during the late Pleistocene (Guilday *et al.*, 1975) and may have been sympatric with both deer and elk during certain phases of glacial recession. No caribou remains were identified from the Clark's Cave deposit.

Table 20. Measurements (in mm) *Mustela erminea* and *Mustela nivalis*, Clark's Cave.

Species	$\bar{X}$	OR	N
Species	length, C - M1		
M. erminea	12.1	12.1	2
	length, P4		
M. erminea	4.4	4.0–4.7	5
M. nivalis	3.36	2.8–3.7	8
	width, P4		
M. erminea	2.12	2.0–2.3	5
M. nivalis	1.75	1.5–2.0	8
	width, M1		
M. erminea	3.65	3.6–3.7	2
M. nivalis	2.65	2.6–2.7	2
	length, m1		
M. erminea	4.2	3.9–4.6	4
M. nivalis	3.48	3.2–3.8	7
	width, m1, talonid		
M. erminea	1.22	1.2–1.3	4
M. nivalis	1.0	0.9–1.1	7

Measurements by Dr. Elaine Anderson.

FAUNAL COMPARISONS—METHODS OF DEPOSITION

The fossil faunas of two mid-Appalachian late Pleistocene small mammal deposits, New Paris No. 4, Pa., and Clark's Cave, Va., represent a sufficient number of individual animals to make statistical comparison possible. Both deposits sampled the same regional fauna in the same physiographic area, the Ridge and Valley section of the mid-Appalachians, during approximately the same time interval. The method of deposition was not the same, however.

At New Paris No. 4, Pa., mammals were trapped by falling down a narrow, vertical fissure 10 m in depth, which filled with accumulating surface debris. At Clark's Cave, most mammal remains represent digestive remains, from raptorial birds, deposited on the talus floor in a sheltered cave entrance.

Despite the different methods of deposition, both faunas were composed almost exclusively of small mammals up to the size of a hare (98% at New Paris No. 4, 99.5% at Clark's Cave). In the former instance, size of entrapped mammals was governed by the small 1.5 m2 entrance, in the latter by the selective bias of the Clark's Cave birds of prey. A casual size analysis of entrapped animals from the two faunas would give no indication of their differing modes of deposition.

The proportion of small-to-large mammals in a raptor deposit is due to the selection bias of the birds of prey, and is independent of the time involved in forming such a deposit. The proportion of small-to-large mammals in a tumble-in trap, like a sinkhole, will increase with time. The slower the rate of infill, the greater the proportion of small-to-large mammals, because of their overwhelming majority in the surrounding fauna. This majority increases their probability of entrapment.

Bat remains were common at both deposits (43% MNI, New Paris No. 4; 36% MNI, Clark's Cave, Va.) but for different reasons. The New Paris No. 4 remains represent natural mortality of a resident population accumulating as infill progressed. The Clark's Cave bats were raptor prey. Bats are usually rare in owl pellet debris, and their presence in such numbers at the Clark's Cave roost reflects the special case of an owl roost situated at the mouth of a large cave containing a flourishing bat population. The numbers of bats at New Paris No. 4 and Clark's Cave do not reflect the difference in the method of deposition at the two sites. There are two clues, however: (1) The sinkhole bat material was exceptionally well-preserved, yielding complete skulls and semi-articulated remains, contrasting with the fragmented collection from Clark's Cave; (2) The New Paris No. 4 sample from a relatively small roost-shaft was dominated by only two species of *Myotis*, with a few *Pipistrellus* and *Eptesicus*. There were at least seven species of bats and five genera in the Clark's Cave deposit, a reflection of the much larger bat roosting area afforded by Clark's Cave and cliffs.

There are minor differences in the composition of the mammalian faunas from the two sites. Those small mammals most suitable for owl prey (shrews, moles, small rodents) were somewhat more common at Clark's Cave (see Table 21), but larger prey items (hares, rabbits) were relatively scarce. Lagomorphs were twice as common in the sinkhole deposit. These differences reflect the selection bias of the raptors. On the basis of these data alone the method of deposition is not apparent.

If one looks at the diversity of the two faunas, more obvious differences appear. Although all major mammal taxa are represented in both faunas, 54 species of mammals were identified from Clark's Cave, but only 40 from New Paris No. 4. The sinkhole sample was derived only from those animals blundering into the small surface opening, while the raptor-accumulated Clark's Cave deposit represents a sampling from many habitats within the cruising range of the birds of prey.

Three other differences in relative numbers are noteworthy—many birds, few snakes, and presence of fish in the raptor roost deposit, compared with the sinkhole trap.

Birds are rarely trapped in vertical fissures, but are common in raptor debris. Two hundred and nineteen birds, of 68 species, 4.8% MNI of combined birds and mammals, were identified from Clark's Cave. At Natural Chimneys, Va., a probable roost site, similar to Clark's Cave, (79 birds, 40 species, or 9.33% of combined birds and mammals), birds were also a common element. In contrast, only nine birds representing seven species, or 0.3%, were present in the New Paris No. 4 sinkhole deposit, a ratio of one bird for every ten in the Clark's Cave deposit.

There was also a discrepancy in relative numbers of snake remains. Minimum numbers of individuals were not accurately ascertained but the number of snake vertebrae compared to the minimum number of mammals from the two sites was 39.1% at Clark's Cave, but 70.9% at New Paris No. 4. There was also a difference in the size of the individual snakes involved. Those at Clark's Cave were small and crotalids were not represented (with the possible exception of one fragmentary vertebra). At New Paris No. 4, however, snakes varied in size from what must have been new-born to large individuals, both colubrids and crotalids. Snakes were a minor food item at Clark's Cave. The raptors avoided large snakes. At New Paris No. 4, however, there was no such selection mechanism and, at least in the upper portions of the fissure deposit, snakes may have sought out the fissure for hibernation.

Turtle and lizard remains in both faunas were either not represented or were negligible. In the case of the turtles at New Paris No. 4 this is probably a reflection of late Pleistocene boreal conditions at the time of infill, for box turtles (*Terrapene carolina*) were common in neighboring sinkholes on the same hillside holding Recent faunal remains. The absence of turtles in an owl roost deposit may be due to raptor selection.

Frogs and toads were common to both sites (6.7% MNI Clark's Cave, 4.9% MNI New Paris No. 4, relative to MNI mammals).

To summarize: On the basis of the bone collections alone, and with no knowledge of the geological situation it is doubtful that one could state that New Paris No. 4 was a sinkhole trap deposit while Clark's Cave was a raptor roost. There are a few differences, but they are relative and mostly take on meaning through hindsight. As more of these faunas are studied, however, the differences noted above may take on greater significance.

Table 21. Mammal composition of two mid-Appalachian cave deposits.

MAMMALS	New Paris No. 4, Pa. Sinkhole Trap			Clark's Cave Raptor Roost		
Taxon	Number of Species	Number of Individuals	Per cent of Individuals	Number of Species	Number of Individuals	Per cent of Individuals
Talpidae – moles	2	3	.10	3	26	.50
Soricidae – shrews	7	107	3.74	7	231	5.30
Chiroptera – bats	4	1235	43.22	8	1554	35.78
Sciuridae – squirrels	6	83	2.90	8	117	2.69
Cricetidae – deermouse, woodrat	3	238	8.33	3	272	6.26
Arvicolidae – voles	10	1213	42.57	9	2060	47.43
Zapodidae – jumping mice	2	17	.59	2	37	.85
Erethizontidae – porcupine	1	3	.10	1	1	.02
Leporidae – rabbits	1	52	1.82	2	24	.55
Carnivora – carnivores	3	5	.17	8	19	.44
Artiodactyla – hoofed animals	1	1	.03	2	2	.04
Totals – Mammal	40	2857		53	4343	
BIRDS	7	9		68	210	
% Total birds to total mammals			.31			4.83

ECOLOGICAL INTERPRETATION

The interpretation of the fauna of the Clark's Cave fossil deposit is clouded by three factors: (1) selective bias of the carnivorous birds responsible for the deposit (influenced by variations in hunting techniques, species of raptors, time of the year roost was occupied, size of prey, hunting radius); (2) great topographic diversity providing a variety of environmental niches; (3) lack of definite knowledge of the time interval represented by the deposit within the rapidly changing framework of late glacial times.

BIRD SUMMARY

Eighty-five species of birds have been reported from three late Pleistocene cave deposits in Virginia: Clark's Cave; Back Creek Cave No. 2, Bath County; and Natural Chimneys, Augusta County. Nine species were common to all three deposits: spruce grouse, *Canachites canadensis*; ruffed grouse, *Bonasa umbellus;* sharp-tailed grouse, *Pedioecetes phasianallus;* bobwhite, *Colinus virginianus;* woodcock, *Philohela minor;* passenger pigeon, *Ectopistes migratorius;* flicker, *Colaptes auratus;* blue jay, *Cyanocitta cristata;* and junco, *Junco hyemalis.* Seventeen additional species were present in at least two of the deposits: blue-winged teal, *Anas discors;* sharp-shinned hawk, *Accipiter striatus;* broad-winged(?) hawk, *Buteo platypterus;* American kestrel, *Falco sparverius;* rock(?) ptarmigan, *Lagopus* cf. *mutus;* turkey, *Meleagris gallopavo;* kingfisher, *Megaceryle alcyon;* red-headed woodpecker, *Melanerpes erythrocephalus;* hairy woodpecker, *Dendrocopos villosus;* downy woodpecker, *Dendrocopos pubescens;* cliff swallow, *Petrochelidon pyrrhonota;* gray jay, *Perisoreus canadensis;* red-breasted nuthatch, *Sitta canadensis;* brown thrasher, *Toxostoma rufum;* robin, *Turdus migratorius;* red-winged blackbird, *Agelaius phoeniceus;* pine grosbeak, *Pinicola enucleator.*

Undue emphasis should not be placed on the presence or absence of a given species of bird, because of predator bias and identification problems inherent in the relatively poor preservation of fragile bird bones. The 26 species listed above were common enough in western Virginia during late Pleistocene times to have appeared in more than one site.

All three sites occur in the intermontane valleys of western Virginia and are roughly comparable in age. The avian fauna complements the paleoecological picture suggested by the mammals. The presence of such relatively sedentary birds as spruce grouse, sharp-tailed grouse, and ptarmigan suggests cooler conditions and an open coniferous parkland—a picture complicated by the topographic diversity of the region, probably presenting a mosaic of open and closed situations.

Only the three species of grouse and the passenger pigeon were present in substantial numbers, a situation that may reflect the collecting bias of the raptors responsible for the deposit rather than their true relative abundance. Ptarmigan and passenger pigeon [although the latter formerly occurred seasonally as far north as James Bay, ca. 52° N. latitude (Todd, 1963] were not normally found in any numbers in the same area within historic times. Their co-presence at Clark's Cave and Back Creek No. 2, assuming they were contemporaneous in the area, which is most likely, was due to the ecological diversity imposed by the mountainous terrain and the ability of birds, both predator and prey, to transgress the bounds of their "normal" habitats, especially if contiguous habitats like open, tundra-like ridge crests and more heavily wooded intermontane valley parklands or bog-forests were to parallel each other throughout the central Appalachians during glacial maxima.

The sharp-tailed grouse and the magpie (*Pica pica*), the latter found only at Natural Chimneys, represent former eastern extensions of their present western ranges (see Fig. 14). Neither species is found in a closed-forest situation today. Their presence suggests semi-prairie or parkland conditions and reinforces a similar conclusion from western elements in the mammal fauna:—13-lined ground squirrel and least chipmunk. There have been undated, but presumably late Pleistocene, finds of badger, *Taxidea taxus*, (Bootlegger Sink, Pa., CM collection, unpublished) and grizzly bear, *Ursus arctos*, (Organ Cave, W. Va., CM 12999) that fit this picture as well.

MAMMAL SUMMARY

Within Recent times 68 species of mammals are known to have inhabited the mid-Appalachians (Table 22, columns 2 and 3). Fifty-four species were identified from the cave deposit (Table 22, columns 1 and 2). Those Recent mammals missing from the deposit were either too large or formidable *(Bison bison, Felis concolor, Lynx rufus, Martes pennanti, Lutra canadensis, Canis lupus, Vulpes vulpes, Urocyon cinereoargenteus, Castor canadensis)* to be taken by most raptors, or were of "southern" distribution (?*Sorex longirostris, Cryptotis parva, Sylvilagus floridanus, Sciurus niger, Reithrodontomys humulis, Ochrotomys nuttalli, Mustela frenata, Spilogale putorius*). The absence of the hoary and silver-haired bats *(Lasiurus cinereus, Lasionycteris notivagans)* is not surprising considering their migratory habits and rarity in and around caves. Three Recent rodents, black rat *(Rattus rattus)*, Norway rat *(Rattus norvegicus)*, house mouse *(Mus musculus)*, Old World forms introduced during the Colonial period, were also absent. Considering its present abundance and its paleogeographic history, the absence of opossum *(Didelphis virginianus)* remains from the site is probably significant. Although reported from the late Pleistocene of Devil's Den, Fla., and Ladds Quarry, Ga., opossum remains have been conspicuously absent from all eastern North America deposits of that period from East Tennessee to Pennsylvania. Even as late as the 16th century, based upon analyses of aboriginal cultural debris (Guilday, 1958), *D. virginianus* was rare or absent in the Northeast, and its spread north to southern Canada and New England was a relatively recent phenomenon. *Sylvilagus floridanus, Sciurus niger, Reithrodontomys* and *Ochrotomys*, based upon their present distributions, seem out of place in a late-glacial boreal setting, and were probably not in the area at the time the deposit was accumulating.

Nine species of mammals found in the deposit do not inhabit the mid-Appalachians today. The dire wolf *(Canis dirus)* is extinct. The remaining eight are all of boreal or mid-Western affinities *(Sorex arcticus, Eutamias minimus, Spermophilus tridecemlineatus,* *Synaptomys borealis, Phenacomys intermedius, Microtus xanthognathus, Mustela erminea, Martes americana).*

If we omit mammals not reasonably considered raptor prey—those species larger than a woodchuck (3 kg±)—thus reducing the selective bias introduced by predator preference, 48 species of medium-to-small-sized mammals were identified from the fossil deposit. Eight of these (16.6%, see above) no longer occur in the mid-Appalachians. An additional 11 (25%) survive at that latitude, at higher elevations in the mountains, and have not been found in the Cowpasture valley *(Condylura cristata, Parascalops breweri, Sorex cinereus, Sorex palustris, Peromyscus maniculatus, Clethrionomys gapperi, Microtus chrotorrhinus, Napaeozapus insignis, Sylvilagus transitionalis, Lepus americanus,* and *Glaucomys sabrinus).* An additional five (10.4%), although still living near the site today, differ in size characteristics from their modern counterparts, agreeing with modern boreal samples of the same species or with those from the late Pleistocene New Paris No. 4 fossil collection *(Blarina brevicauda, Tamias striatus, Tamiasciurus hudsonicus, Glaucomys volans,* and *Synaptomys cooperi).*

The mammalian fauna of the Clark's Cave deposit is almost identical with that of New Paris No. 4, Pa. Differences can be ascribed to its more southerly location (absence of *Dicrostonyx,* higher numbers of *Sorex fumeus, Microtus pinetorum,* and *Peromyscus leucopus*), possible accidents of deposition and sampling (presence of *Eutamias minimus* at Clark's Cave, but not at New Paris No. 4), or predator bias (absence of *Mylohyus* and larger variety of bats at Clark's Cave). The activity of raptors was also apparent in the greater number of birds from Clark's Cave. Those boreal forms represented at Clark's Cave but not at New Paris No. 4,—ptarmigan, spruce grouse, gray jay—may simply not have been trapped in the tumble-in sinkhole at New Paris No. 4.

The bulk of the recovered fauna, as at New Paris No. 4, suggests that the predominate vegetative cover was an open boreal woodland dominated by conifers. Topographical diversity undoubtedly produced, as it does today, a variety of ecological niches. The only significant difference between the two faunas was the presence of the collared lemming, *Dicrostonyx hudsonius*, at New Paris No. 4, Pa., but not at Clark's Cave. As the Clark's Cave raptors concentrated on voles as a major prey item, the absence of the collared lemming at Clark's strongly suggests the absence of paucity of tundra in the Cowpasture valley or its neighboring mountain walls. Tundra conditions somewhere in the area are suggested by the presence of bones of the more vagile ptarmigan both at Clark's Cave and at Back Creek Cave No. 2, 24 km to the west. The evidence to date suggests that while tundra may have extended down the Appalachians to at least the latitude of New Paris No. 4, Pa. *(Dicrostonyx)* and Buckle's Bog, Md. (pollen profile, Maxwell & Davis, 1972), its presence as far south as west-central Virginia may have been discontinuous.

In common with the mammals recovered from Clark's Cave, no species of bird found solely to the south of Virginia today was recovered. All species occur in the state today or farther to the north and northwest (spruce grouse, sharp-tailed grouse, gray jay, pine grosbeak, and rock (?) ptarmigan). In summary, the recovered mammal fauna agrees in its ecological implications with the bird fauna in the absence of "southern" species and the influx of northern and western forms.

A shortcoming of a fossil raptor roost like the Clark's Cave deposit, is the virtual absence of large mammals because of the selection bias of the birds. There are large late Pleistocene mammals known from western Virginia in local faunas, unaccompanied by smaller vertebrates, so that the fuller picture must be pieced together from several sites that may or may not have been exactly contemporaneous. Ground sloth, *Megalonyx;* mammoth, *Mammuthus primigenius;* mastodon, *Mammut americanum;* horse, *Equus;* caribou, *Rangifer tarandus;* extinct moose, *Cervalces;* bison, *Bison;* extinct muskoxen, *Symbos* and *Bootherium;* have been recovered from Saltville, Smythe County, Va., southwest of Clark's Cave, associated with a date of 13,460 radiocarbon years. The pollen associated with the muskox remains (Ray *et al.,* 1967) indicated a flora dominated by spruce and pine, and was interpreted as spruce parkland interspersed with ponds, marshes, and prairies, an environment similar to that suggested by the Clark's Cave local fauna. These large herbivores were attracted to and mired in saline springs. Molars of the giant beaver (*Castoroides ohioensis*) have been recovered from Natural Chimneys, Va. Long-nosed peccary *Mylohyus nasutus* is known from Natural Chimneys and Back Creek No. 1, Va. There is archaeological evidence from Russell Cave, Ala., that *Mylohyus nasutus* may have survived as late as 7,000 years ago. No direct evidence links any of these large animals with the Clark's Cave local fauna, but they probably coexisted with it.

Table 22. Species of mammals, Clark's Cave, and Recent mid-Appalachians. ( ) = MNI, fossil deposit.

Present in Clark's Cave deposit only	Present in Clark's Cave deposit and Recent mid-Appalachians	Present in Recent mid-Appalachians only
	Family Didelphiidae	
		Didelphis virginianus
	Family Talpidae	
	Condylura cristata (13)	
	Parascalops breweri (12)	
	Scalopus aquaticus (1)	
	Family Soricidae	
Sorex arcticus (13)	*Sorex cinereus* (67)	*Sorex longirostris*
	Sorex dispar (4)	
	Sorex fumeus (10)	*Cryptotis parva*
	Sorex palustris (7)	
	Microsorex hoyi (7)	
	Blarina brevicauda (97)	
	Family Vespertilionidae	
	Myotis lucifugus/sodalis *Myotis keenii* (c. 877)	*Lasionycteris noctivagans*
	Myotis leibii (c. 138)	*Lasiurus cinereus*
	Myotis grisescens (c. 138)	
	Eptesicus fuscus (363)	
	Pipistrellus subflavus (26)	
	Plecotus townsendii (9)	
	Lasiurus borealis (3)	
	Family Leporidae	
	Lepus americanus (23)	*Sylvilagus floridanus*
	Sylvilagus transitionalis (1)	
	Family Sciuridae	
Eutamias minimus (3)	*Tamias striatus* (24)	*Sciurus niger*
Spermophilus tridecemlineatus (5)	*Marmota monax* (2)	
	Tamiasciurus hudsonicus (25)	
	Sciurus carolinensis (3)	
	Glaucomys volans (19)	
	Glaucomys sabrinus (28)	
	Family Castoridae	
		Castor canadensis
	Family Cricetidae	
	Peromyscus maniculatus (c. 117)	*Reithrodontomys humulis*
	Peromyscus leucopus (c. 104)	*Ochrotomys nuttalli*
	Neotoma floridana (51)	
	Family Arvicolidae	
Synaptomys borealis (61)	*Synaptomys cooperi* (23)	
Phenacomys intermedius (34)	*Clethrionomys gapperi* (305)	
Microtus xanthognathus (511)	*Microtus pennsylvanicus* (c. 658)	
	Microtus chrotorrhinus (c. 292)	
	Microtus pinetorum (170)	
	Ondatra zibethicus (6)	

Table 22. Species of mammals, Clark's Cave, and Recent mid-Appalachians. ( ) = MNI, fossil deposit (continued).

Present in Clark's Cave deposit only	Present in Clark's Cave deposit and Recent mid-Appalachians	Present in Recent mid-Appalachians only
	Family Muridae	
		Rattus rattus
		Rattus norvegicus
		Mus musculus
	Family Zapodidae	
	Zapus hudsonius (22)	
	Napaeozapus insignis (15)	
	Family Erethizontidae	
	Erethizon dorsatum (1)	
	Family Canidae	
Canis cf. *dirus* (1)		*Canis lupus*
		Vulpes vulpes
		Urocyon cinereoargenteus
	Family Ursidae	
	Ursus americanus (1)	
	Family Procyonidae	
	Procyon lotor (1)	
	Family Mustelidae	
Martes americana (1)	*Mustela nivalis* (7)	*Martes pennanti*
Mustela erminea (4)	*Mustela vison* (2)	*Mustela frenata*
	Mephitis mephitis (1)	*Spilogale putorius*
		Lutra canadensis
	Family Felidae	
		Felis concolor
		Lynx rufus
	Family Cervidae	
	Cervus elaphus (1)	
	Odocoileus virginianus (1)	
	Family Bovidae	
		Bison bison

AGE OF DEPOSIT

It is clear, from the presence of so many boreal birds and mammals, that the deposit accumulated during a cooler climatic episode. The mammalian fauna, with minor exceptions, is identical with that of New Paris No. 4, Pa. (11,000 years B.P.), even to infraspecific size (Bergmann's Response). This, plus the relatively superficial nature of the deposit scattered throughout the upper 45 cm of an unconsolidated cliff talus, indicates a relatively late date, but one predating the Recent fauna and flora.

Deposition could not have extended very far, if at all, into Recent times on a sustained basis. In addition to the negative evidence of the absence of introduced or domestic species of birds and mammals, the size characteristics of the fossil population samples of species like *Sorex cinereus, Blarina brevicauda, Condylura cristata, Tamias striatus, Tamiasciurus hudsonicus, Glaucomys volans, Glaucomys sabrinus, Lepus americanus, Synaptomys cooperi,* and *Napaeozapus insignis* are distinct from their Recent mid-Appalachian representatives, paralleling those of New Paris No. 4, Pa. If deposition at the site had continued into Recent times there should have been a size-continuum between the late Pleistocene and Recent representatives within each species, expressed as an increase in variation, larger observed ranges, and higher coefficients of variation. Such was not the case. Deposition must have halted, for all practical purposes, before these mammals showed any degree of measurable physiological adjustment to the changing environment.

Judging from the rate of accumulation of modern "owl-roosts," the Clark's Cave deposit was built up in a relatively short time, probably between 20,000 and 11,000 years ago—a concentrated accumulation of an active population of both adult and fledgling raptors. Deposition may have been terminated by rockfalls, but this is not apparent at the site today, and the deposit was not buried under rock debris. The abandonment of the roost as a nesting site may have been hastened by Indian molestation in this easily accessible river-bank nesting site. Wayne C. Clark, Assistant Archaeologist, Archaeological Society of Virginia (letter, Oct. 1, 1975) reports 32 Prehistoric Indian sites from Bath County alone, dating primarily from 8,000 B.C. to 1,600 A.D., with the majority of the large sites dating to the Woodland period, ca. 1,000 B.C. to 1,600 A.D., so that the Clark's Cave raptors could have been subject to human predation for at least the last 10,000 years. This is speculation, however. Any evidence of a prehistoric occupation in any of the larger entrances of Clark's Cave would have been destroyed by the Colonial and Civil War saltpeter miners.

If we assume that deposition ceased at the site prior to Recent times, there are a few seeming anomalies—the presence of the woodland vole *(Microtus pinetorum)* and the white-footed mouse *(Peromyscus leucopus)* in greater numbers than one would expect in a boreal environment suggests either that they were able to adjust to the periglacial conditions at this latitude or, perhaps, were pioneer colonizers in the ecological ferment of postglacial warming. Both species are inhabitants of dry, deciduous, hardwood forests, but occur locally in northern New England today in cool hemlock/maple woods of Canadian aspect. The presence of a single individual of the eastern mole *(Scalopus aquaticus)* appears anomalous, based on its present geographic distribution, as well as of birds like the bobwhite, *Colinus virginianus* (two individuals), and one individual each of orchard oriole *Icterus spurius,* tanager *Piranga* ?species, and a questionable red-bellied woodpecker *Centurus carolinus.* Owls still roost on the Clark's cliffs, however, and a scattering of Recent remains may have been introduced into the deposit.

A C14 date of 2,260+ 85 years B.P., based on bone carbonate, was obtained from a sample of 215 gms of unsorted bone fragments (I-7224). This date is obviously too recent. The superficial nature of the deposit increased the chances of contamination and the date is unacceptable as far as dating the Clark's Cave deposit is concerned.

THE LATE GLACIAL ENVIRONMENT

Late glacial climatic changes and their biological consequences are still known only in broadest outline. Data have accumulated from geological and biological sources, both marine and terrestrial—frost and ice phenomena, plant fossils including pollen, invertebrate and vertebrate fossils—that point to effects of glacial cooling extending to lower latitudes hundreds of kilometers south of the terminal Wisconsinan moraine.

The extent and direction of environmental change in the Appalachians is governed by the regional topography—long, parallel mountain ridges interspersed with intermontane valleys extending southwards in essentially unbroken array from the former glacial front to the Carolinas and Georgia, culminating in the Great Smoky Mountains. The effect of such topography is seen today in the distribution of forest types.

> ". . . The long southward projection of the northern hardwood forests on the Appalachian summits today probably had a full glacial predecessor in the form of tundra and boreal forest. Such a projection could have been a main avenue for the invasion of boreal elements into the boreal forests

of the time." (Flint, 1971:509)

Evidenee of glaeial eooling refleeted in the distribution of boreal species of plants during full glacial times (Watts, 1970) has been recorded from as far south as Georgia and northern Florida. We will concentrate on climatic changes in the central Appalachian West Virginia/Virginia area and their relationship to Clark's Cave (see V. A. Carbone's excellent survey of the late-glacial environment in the neighboring Shenandoah Valley, Va., in Gardner, 1974:84-99).

There is evidence from several sources for the former occurrence of Wisconsinan-age tundra, *i.e.,* open, treeless grass and sedge expanses and permafrost in the Appalachian highlands south of the terminal moraine. The most dramatic claim, former alpine glaciation at Boone Fork, Grandfather Mountain, N.C. at 36° O′ N. (Berkland & Raymond, 1973), has been rejected. It was based upon parallel grooves, worn into rock outcrops by metal logging cables, that were misinterpreted as glacial striations (McKeon, 1974; Hack & Newell, 1974; Berkland & Raymond, 1974). But the presence of block fields and of patterned-ground relicts on ridge crests from Pennsylvania to southern Virginia at altitudes ranging from 707 m in central Pennsylvania (Riansares) to 1,615 m (Whitetop Mountain) on the Tennessee/Virginia/North Carolina border (Clark, 1968, in Flint, 1971:283) suggests former permafrost activity. These sites are undated and may conceivably have predated the Wisconsinan glaciation. Direct evidence of Wisconsinan age tundra in the central Appalachians rest upon the evidence of plant and animal fossils. A pollen profile extending back into full glacial times is known from Buckle's Bog, Md., at the headwaters of the Casselman River, at an elevation of 814 m, 170 km north of Clark's Cave on the eastern rim of the Appalachian Plateau. Maxwell and Davis (1972), studied a 258 cm core from Buckle's Bog and interpreted the lowermost 66 cm (zone BB-1), dated from 19,000 to 12,700 radiocarbon years, as true tundra. Nonarboreal pollen, over 50% sedges and grasses, predominated. Spruce (10-22%) and pine (5-17%) were the dominant arboreal pollen. The authors construed the relatively high percentage of spruce to pine as indicative of the nearby spruce, perhaps in sheltered valleys within 25 km of the site. Pine pollen, shed in greater abundance and more widely wind-distributed, should have been present in greater relative amounts if spruce were not locally present.

The faunal evidence for the former presence of tundra, although not as extensive as that obtained from pollen analysis, is highly suggestive. Direct historical continuity between the Wisconsinan low-latitude periglacial tundra and the Recent eastern Canadian tundra is indicated by the skeletal remains of the Hudson's Bay collared lemming, *Dicrostonyx hudsonius*, at 11,300 radiocarbon years, from New Paris No. 4, Pa., at the relatively low altitude of 465 m, just 16 km east of the rim of the Appalachian Plateau. The ptarmigan, *Lagopus* sp., reported in this paper from Clark's Cave and nearby Back Creek No. 2 Cave, also suggests the near presence of tundra or tundra-like conditions. Because birds are more mobile than mammals and the possibility exists that the ptarmigan may be the willow rather than the rock ptarmigan, the evidence is not as firm as at New Paris No. 4. But at least, nearby open ground is indicated. Other boreal species, recorded from cave deposits as far south as 36° latitude in Tennessee (the caribou, *Rangifer tarandus*), 34° latitude Georgia (the spruce grouse, *Canachites canadensis*), and porcupine from the Coleman IIA fauna, Fla., 29° latitude, indicate just how far south mammalian adjustments occurred.

Changes in forest composition following the Wisconsinan glacial recession were first noted at about 13,600 radiocarbon years as a shift from coniferous to deciduous species in Georgia. But, on the basis of radiocarbon dating, approximately 1,000 more years were required for floral changes to be noted in the higher and more northern Appalachian plateau and ridge provinces as a change from tundra vegetation to boreal woodland (Maxwell & Davis, 1972). The situation at Clark's Cave at this time was somewhat different. The broad expanse of the Appalachian Plateau flanking the northwestern approaches to the Appalachian ridges served as a wind and precipitation shield between them and the continental glaciers (Fig. 2 insert). Consequently the intermontane valleys to the east were protected from the full climatic rigors of the period. Pollen analyses at Hack and Querles ponds, on the floor of the Shenandoah valley, near Staunton, Va. (Craig, 1969), indicate that at the time tundra was noted at Buckle's Bog and, by extension, from the higher ridges of the Appalachian Plateau and Mountains, the protected valley floors supported an open spruce and pine woodland. And as the tundra gave way to open spruce woodland in the higher Alleghenies between 12,700 and 10,000 radiocarbon years, the spruce woodlands of the protected intermontane valleys were changing to mixed closed-canopied forests of spruce, pine and hardwoods.

The late Pleistocene vegetation of the Clark's Cave area during the deposition of the fossil deposit is hard to categorize because of the rugged terrain. Local topographical relief is some 500 m within a few kilometers of the site. Topography varies from flat flood plain to cliff and mountainous terrain. The picture derived from the fauna itself can only be a montage, but full glacial conditions in the Cowpasture River valley can be visualized as a spruce parkland. The flood plain was probably dotted with copses of spruce intermingled with prairie, marshes, and small ponds. The shale hills along the eastern margin of the river valley that now support a xeric shale-barren flora were, in all probability, relatively dry then, perhaps supporting jackpine (*Pinus banksiana*) parklands. The presence of marshes or small standing-water ponds is suggested by grebes, bitterns, ducks, rails, plovers, and sandpipers, (26% of the identified species of birds from the deposit) and the number and variety of frogs.

Coniferous to deciduous change in forest composition proeeeded with great rapidity. This was reflected in the changing make-up of the vertebrate fauna. Most of the mammals present during boreal times either migrated to higher latitudes, underwent physiological adjustment, or especially in the case of the larger species, became extinct. Three carbon dates associated with mammalian faunas in Pennsylvania are relevant. At 11,300 radiocarbon years, the fauna of New Paris No. 4, Pa., was dominated by boreal small rodents and insectivores. By 8,570 radiocarbon years, the fauna from New Paris sinkhole No. 3 at New Paris, situated within a few meters of sinkhole No. 4, was a Recent one with no trace of the boreal species that so dominated the latter site. The mammalian fauna associated with a date of 9,240 radiocarbon years at Hosterman's Pit, Pa., 136 km northeast of New Paris, was likewise Recent in species composition. This suggests that a radiogenically undated deposit like that at Clark's Cave can be assigned a rather definite age limit (minimum if boreal in make-up, maximum if composed of Recent species).

Following the period of initial coniferous/deciduous floral turnover, the region has been characterized by a closed-canopy, oak-dominated deciduous forest. There have been minor climatic changes reflected in relative forest composition, successive submaxima of hemlock (*Tsuga*), chestnut (*Castanea*), and hickories (*Carya*) that probably required little, if any, adjustment on the part of at least the larger mammals. Changes of this magnitude may not be monitored by deposits like the Clark's Cave fossil assemblage that are not as sensitive as pollen sites to minor climatic oscillations.

The Clark's Cave local fauna with its mixture of forest and meadow forms and its boreal, continental aspect suggests several distinct habitats within the hunting radius of the cave-based raptors. The climatic model of Saltzman and Vernekar (1975) suggests that the Full Glacial averaged macroclimate of the Holarctic ice border was cold and dry with reduced precipitation and evaporation. Channel-scouring and downcutting in late glacial fluvial deposits of the South Fork Potomac River, northeast of Clark's Cave, suggests increased stream velocity and run-off attributed to decreased evaporation (Gardner, 1974).

This suggests that the floor of the Cowpasture River valley may have been relatively more mesic than the surrounding high-relief uplands because of a higher regional water table and the pooling of slope run-off caused by lower evaporation rates. The extensive flood plain (Fig. 10) probably developed boreal bogs and grass and sedge wetlands, while the relatively xeric uplands supported coniferous scattered woodlands, their density depending upon local hydrologic conditions. Such an environment would satisfy the mixed requirements of the varied fossil assemblage, allowing the raptors to draw from contiguous but contrasting habitats.

The most disturbing aspect of the deposit is the lack of an absolute date within the Wisconsinan late glacial period. Only one fully comparable deposit has been studied in the area, New Paris No. 4, Pa. Perhaps this will remedy itself when more sites are developed and temporal faunal changes with refugial survivals are documented in the mid-Appalachians during the late Pleistocene.

LIFE ZONE INTEGRITY

The view that periglacial biotic adjustment to continental glaeial oscillations was essentially just latitudinal and altitudinal shifting of present life-zone systems is no longer tenable. The initial picture presented by pollen analysis could evoke several interpretations because it was possible to study only

Table 23. Site References.

Site	Age	Type of Site	Reference
Alabama			
Russell Cave	c. 7 – 9,000 yrs. B.P.	Cave	Weigel *et al.*, 1974
Arkansas			
Conard Fissure	Irvingtonian	Cave, fissure	Graham, 1972; Brown, 1908
Peccary Cave, Newton Co.	2,230± 120 yrs. B.P. 16,700± 250 yrs. B.P.	Cave	Davis, 1969; Quinn, 1972; Semken, 1969
Florida			
Coleman IIA, Sumter Co.	"Middle Pleistocene"	Sinkhole	Martin, 1974
Devil's Den, Levy Co.	Late Pleistocene/early Holocene	Sinkhole	Martin & Webb, 1974
Georgia			
Ladds Quarry, Bartow Co.	Rancholabrean	Fissure	Ray, 1965, 1967; Lipps & Ray, 1967; Wetmore, 1967
Idaho			
Jaguar Cave, Lemhi Co.	10,370± 350 yrs. B.P. 11,580± 250 yrs. B.P.	Cave	Guilday & Adams, 1967; Kurten & Anderson, 1972
Wilson Butte, Jerome Co.	4,890± 300 yrs. B.P. (M-1087) 15,000± 800 yrs. B.P. (M-1410)	Cave	Gruhn, 1961, 1965
Illinois			
Meyer Cave, Monroe Co.	Early Holocene	Fissure	Parmalee, 1967
Iowa			
Brayton local fauna, Audubon Co.	12,420± 180 yrs. B.P.	Fluvial	Dulian, 1975
Waubonsie local fauna, Mills Co.	"late Wisconsinan"	Fluvial	Hallberg *et al.*, 1974
Kentucky			
Welsh Cave, Woodford Co.	12,950± 550 yrs. B.P. (I-2982)	Cave, sinkhole	Guilday *et al.*, 1971
Maryland			
Cumberland Cave, Allegany Co.	Irvingtonian	Cave, fissure	Gidley & Gazin, 1938
Minnesota			
Itasca Bison Site, Clearwater Co.	7 – 8,000 yrs. B.P.	Bison kill, Fluvial	Shay, 1971
Missouri			
Bat Cave, Pulaski Co.	Rancholabrean	Cave	Hawksley, *et al.*, 1973
Crankshaft Cave, Jefferson Co.	Late Pleistocene/Recent	Sinkhole	Parmalee, *et al.*, 1969
Pennsylvania			
Bootlegger Sink, York Co.	Rancholabrean/early Holocene	Cave, sinkhole	Guilday, *et al.*, 1966
Hosterman's Pit, Centre Co.	9,240± 1,000 yrs. B.P. (M-1291)	Cave	Guilday, 1967
New Paris No. 2, Bedford Co.	1,875± 100 yrs. B.P. (I-743)	Sinkhole	Guilday & Bender, 1958
New Paris No. 3, Bedford Co.	8,570± 145 yrs. B.P. (I-5313)	Sinkhole	CMNH unpubl.
New Paris No. 4, Bedford Co.	11,300± 1,000 yrs. B.P. (Y-727)	Sinkhole	Guilday *et al.*, 1964
Sheep Rock Shelter, Huntingdon Co.	490± 100 yrs. B.P. (M-1904) 8,920± 320 yrs. B.P. (M-1909)	Rockshelter	Guilday & Parmalee 1965; Michels & Smith, 1967
Tennessee			
Baker Bluff Cave, Sullivan Co.	10,560± 220 yrs. B.P. } (GX 3370) 11,640± 250 yrs. B.P. } 19,100± 850 yrs. B.P. (GX 3495)	Cave, fissure	Guilday *et al.*, 1975
Guy Wilson Cave, Sullivan Co.	19,700± 600 yrs. B.P. (I-4163)	Cave	Guilday *et al.*, 1975
Robinson Cave, Overton Co.	Rancholabrean	Cave	Guilday *et al.*, 1969
Virginia			
Back Creek Cave No. 1 (Cook Cave), Bath Co.	Rancholabrean	Rockshelter, owl roost	CMNH coll., unpubl.

Table 23. Site References (continued).

Site	Age	Type of Site	Reference
Virginia (continued)			
Back Creek Cave No. 2 (Sheets Cave), Bath Co.	Rancholabrean	Rockshelter, owl roost	CMNH coll., unpubl.
Natural Chimneys, Augusta Co.	Rancholabrean	Cave, owl roost	Guilday, 1962
Saltville	13,460± 420 yrs. B.P. (SI-461)	Paludal	Ray *et al.*, 1967

a portion of the fossil flora (those plants possessing identifiable wind-distributed pollen). Only a generalized conception of the sampled paleoenvironment was possible. Anomalous deciduous pollen present in an otherwise boreal pollen profile was always susceptible to the interpretation that it was not indigenous, but wind-transported from a distance. Remains of large Pleistocene mammals, mostly those of extinct herbivores (proboscideans, ovibovines, sloths, cervids) and carnivores could supply little to the detailed ecological picture.

Pollen analysis supplied the outlines of biotic adjustment in lower latitudes, and convincingly demonstrated that the magnitude of change was much greater than that suggested by earlier workers who lived prior to the advent of palynology as a research tool (Braun, 1950). But the question of the detailed biotic composition of these adjustments, whether they represented simple biome fluctuations or resulted in new and unique combinations, remained open until paleontological sites of late Pleistocene age, containing remains of ecologically sensitive small vertebrates of known Recent habitat, were discovered and analyzed.

Initiated in modern form by the late C. W. Hibbard (Hibbard, 1949), techniques for recovering microvertebrates soon demonstrated that periglacial faunas were composed of an amalgam of temperate and boreal species, and that the fossil faunas, even though composed of Recent forms, could not be duplicated today at any latitude. Initial analysis of such sites consisted of constructing overlap maps (like Fig. 18, this paper) in which the Recent ranges of the various recovered species were superimposed on one another and the area of maximum overlap was considered an approximation, or, at the least, an indication of former environments.

It is becoming obvious that modern boreal terrestrial environments cannot be considered analogous to late Pleistocene situations in lower latitudes. Even if the climate could be duplicated precisely, which is not possible, differences in topography, geology, and the historical development of their respective biotas could not. Modern eastern North American boreal biotas are composed largely of post-Wisconsinan immigrants occupying deglaciated terrain that had been stripped of living things by glacial ice. Hence a competative edge was given to those species preadapted for a harsh boreal environment and capable of rapid spreading. Southern periglacial faunas, on the other hand, were composed of both boreal forms and those temperate species that could survive either in local refugia or in various degrees of integration in an unglaciated situation. Periglacial habitats were not created and destroyed with the rapidity of those once covered by ice, but adjusted slowly and less dramatically with climatic change, creating a fluid mosaic of environmental niches supporting a richer biota than would be the case if that biota had to start anew (as in once-glaciated areas) with no historical continuity.

Work by Dr. Holmes Semken, University of Iowa, and his students on late Pleistocene faunas from the Midwest demonstrated that this is true even for areas of little topographic diversity. Although different species are involved, the picture becomes even more complicated in the Appalachian Mountains where highlands and lowlands parallel each other alternately for hundreds of kilometers in a north-south direction. The richness of the Clark's Cave local fauna, compared to the more boreal New Paris No. 4 fauna, 240 km to the north, appears to express this biotic gradient. In addition to this boreal-temperate intermesh, a cross-mesh of eastern forest and now mid-western forms occurred, producing a unique fauna that cannot be analyzed in the light of the present-day habitat requirements of each species taken individually. Each component species was responding not only to environmental pressures, but to pressures resulting from new and unique combinations of species, so that the definitive environmental picture of that time and place may not be the sum of its component parts as suggested by the Recent ecological requirements of each of the species involved.

Literature Cited

American Ornithologists' Union
1957. Check-list of North American birds, 5th ed., Lord Baltimore Press, Baltimore, Md. 691 pp.

Anderson, Rudolph
1947. Catalogue of Canadian Recent mammals. Natl. Mus. Canada Bull. 102. 238 pp.

Bailey, John Wendell
1946. The mammals of Virginia. Williams Printing Co., Richmond, Va. i-xvi + 416 pp.

Baird, S. F.
1857. Reports of explorations and surveys, Part 1, Mammals. V. 8, 757 pp.

Banfield, A. W. F.
1974. The mammals of Canada. Univ. of Toronto Press. pp. v-xxv; 1-438.

Barkalow, Frederick S. Jr.
1961. The porcupine and fisher in Alabama archaeological sites. Jour. Mammal., 42(4):544-545.

Bent, Arthur C.
1932. Life histories of North American gallinaceous birds. U. S. Natl. Mus. Bull. 162. 490 pp.
1938. Life histories of North American birds of prey (Part 2). U. S. Natl. Mus. Bull. 170. 482 pp.
1942. Life histories of North American flycatchers, larks, swallows, and their allies. U. S. Natl. Mus. Bull. 179. 555 pp.

Berkland, James O., and Loren C. Raymond
1973. Pleistocene glaciation in the Blue Ridge Province, Southern Appalachian Mountains, North Carolina. Science, 181:651-653.
1974. Letter to the Editor. Science, 184:89-91.

Bick, Kenneth F.
1962. Geology of the Williamsville Quadrangle Virginia report of investigations 2, Va. Div. Miner. Resour., Charlottesville. 40 pp.

Bole, B. Patterson, Jr., and Philip N. Moulthrop
1942. The Ohio Recent mammal collection in the Cleveland Museum of Natural History. Sci. Publ. Cleveland Mus. Nat. Hist., V(6):83-181.

Braun, E. Lucy
1950. Deciduous forests of eastern North America. The Blakiston Co., Philadelphia and Toronto. 596 pp.

Brooks, Maurice
1943. Birds of the Cheat Mountains. The Cardinal, 6(2):25-45.

Brown, Barnum
1908. The Conard Fissure, a Pleistocene bone deposit in northern Arkansas; with descriptions of two new genera and twenty new species of mammals. Mem. Amer. Mus. Nat. Hist., 9(4):155-204.

Bryson, Reid A., Wayne M. Wendland, Jack D. Ives, and John T. Andrews
1969. Radiocarbon isochrones on the disintegration of the Laurentide Ice Sheet. Arctic and Alpine Res., 1(1):1-13.

Cameron, Austin W.
1950. A new chipmunk *(Tamias)* from Ontario and Quebec. Jour. Mammal. 31(3):347-348.

Carbone, Victor A.
1974. The Paleo-environment of the Shenandoah Valley. *In* Gardner, William M., ed., The Flint Run Paleo-Indian Complex: A preliminary report 1971-1973 Seasons. Occas. Publ. 1, Dept. of Anthrop., The Catholic Univ. of Amer. pp. 84-99.

Clark, G. M.
1968. Sorted patterned ground: new Appalachian localities south of the glacial border. Science. 161:355-356.

Clarkson, Roy B.
1966. The vascular flora of the Monongahela National Forest, West Virginia. Castanea. 31(1):1-119.

Conaway, Clinton H., and Donald W. Pfitzer
1952. *Sorex palustris* and *Sorex dispar* from the Great Smoky Mountains National Park. Jour. Mammal. 33(1):106-108.

Core, Earl L.
1974. Vegetation of West Virginia. McClain Printing Co., Parsons, W. Va. 217 pp.

Craig, Alan J.
1969. Vegetational history of the Shenandoah Valley, Virginia. *In* U. S. Contrib. Quat. Res., Geol. Soc. of Amer. Spec. Papers 123, Boulder, Colo. pp. 283-296.

Cushing, Edward J.
1965. Problems in the Quaternary Phytogeography of the Great Lakes Region. *In* Wright, H. E. Jr., and David G. Frey, eds., The Quaternary of the United States. Princeton Univ. Press. pp. 403-416.

Davis, L. C.
1969. The biostratigraphy of Peccary Cave, Newton County, Arkansas. Proc. Arkansas Acad. Sci., 23:192-196.

Dice, Lee R.
1943. The biotic provinces of North America. Univ. Michigan Press, Ann Arbor. 78 pp.

Doutt, J Kenneth, Caroline A. Heppenstall, and John E. Guilday
1973. Mammals of Pennsylvania. 3rd ed. Pa. Game Comm., Harrisburg, Pa. 288 pp.

Dulian, James Joseph
[MS thesis] Paleoecology of the Brayton Local Biota, Late Wisconsinan of southwestern Iowa. Dept. of Geol., Univ. Iowa.

Faust, Burton S.
1964. The Saltpetre Caves of Virginia. *In* Douglass, Henry H., ed., Caves of Virginia, Virginia Region of the Natl. Speleo. Soc., Virginia Cave Survey, Falls Church. pp. 31-56.

Flint, Richard Foster
1971. Glacial and Quaternary Geology. John Wiley & Sons, Inc. 892 pp.

Galbreath, Edwin C.
1964. A dire wolf skeleton and Powder Mill Creek Cave, Missouri. Trans. Ill. State Acad. Sci. 57(4):224-242.

Gardner, William M., ed.
1974. The Flint Run Paleo-Indian Complex; a preliminary report 1971-73 seasons. Occas. Publ. No. 1, Dept. of Anthrop., The Catholic Univ. of Amer. 146 pp.

Gidley, John W., and C. Lewis Gazin
1938. The Pleistocene vertebrate fauna from Cumberland Cave, Maryland. U. S. Natl. Mus. Bull. 171:1-99.

Gillette, David D., and John D. Kimbrough
1970. Chiropteran mortality. *In* Slaughter & Walton, eds., About Bats. South. Methodist Univ. Press. pp. 262-283.

Godfrey, W. E.
1966. The birds of Canada. Natl. Mus. Canada Bull. 203. 428 pp.

Graham, Russell William
[MS thesis] Biostratigraphy and paleoecological significance of the Conard Fissure local fauna with emphasis on the genus *Blarina*. Dept. of Geol., Univ. of Iowa; unpubl.

Gruhn, Ruth
1961. The archaeology of Wilson Butte Cave, southcentral Idaho. Occas. Papers Idaho State Coll. Mus. No. 6. 202 pp.
1965. Two early radiocarbon dates from the lower levels of Wilson Butte Cave, southcentral Idaho. Tebiwa, Jour. Idaho State Mus. 8(2):57.

Guilday, John E.
1958. The prehistoric distribution of the opossum. Jour. Mammal. 39:39-43.
1961a. Prehistoric record of *Scalopus* from Western Pennsylvania. Jour. Mammal. 42(1):117-118.
1961b. *Plecotus* from the Pleistocene of Pennsylvania. Jour. Mammal. 42:402-403.
1962. The Pleistocene local fauna of the Natural Chimneys, Augusta County, Virginia. Ann. Carnegie Mus., 36(9): 87-122.
1963. Pleistocene zoogeography of the collared lemming (Dicrostonyx). Evolution, 17(2):194-197.
1967. The climatic significance of the Hosterman's Pit local fauna, Centre County, Pennsylvania. Amer. Antiquity, 32(2):231-232.

Guilday, John E., and Eleanor Adam
1967. Small mammal remains from Jaguar Cave, Lemhi County, Idaho. Tebiwa, Jour. Idaho State Mus. 10(1): 23-36.

Guilday, John E., and Martin S. Bender
1958. A Recent fissure deposit in Bedford County, Pennsylvania. Ann. Carnegie Mus. 35:127-138.

Guilday, John E., Harold Hamilton, and Allen D. McCrady
1966. The bone breccia of Bootlegger Sink, York County, Pennsylvania. Ann. Carnegie Mus. 38(8):145-163.

Guilday, John E., H. W. Hamilton, and A. D. McCrady
1969. The Pleistocene vertebrate fauna of Robinson Cave, Overton County, Tennessee. Palaeovertebrata. 2:25-75.

Guilday, John E., Harold W. Hamilton, and Allen D. McCrady
1971. The Welsh Cave peccaries *(Platygonus)* and associated fauna, Kentucky Pleistocene. Ann. Carnegie Mus. 43: 249-320.

Guilday, John E., Harold W. Hamilton, and Paul W. Parmalee
1975. Caribou *(Rangifer tarandus* L.) from the Pleistocene of Tennessee. Jour. Tenn. Acad. Sci. 50(3):109-112.

Guilday, John E., Paul S. Martin, and Allen D McCrady
1964. New Paris No. 4: A Pleistocene cave deposit in Bedford County, Pennsylvania. Bull. Natl. Speleo. Soc. 26(4): 121-194.

Guilday, John E., and Paul W. Parmalee
1965. Animal remains from the Sheep Rock Shelter (36 Hu 1), Huntingdon County, Pennsylvania. Pa. Archaeologist. 35(1):34-49.

Guilday, John E., and Paul W. Parmalee
1972. Quaternary periglacial records of voles of the genus *Phenacomys* Merriam (Cricetidae:Rodentia). Quat. Res. 2:170-175.

Hack, John T., and John C. Goodlett
1960. Geomorphology and forest ecology of a mountain region in the central Appalachians. U. S. Geol. Surv. Prof. Paper No. 347. pp. 1-64.

Hack, John T., and Wayne L. Newell
1974. Letter to the editor. Science. 184:89.

Hallberg, George R., Holmes A. Semken, and L. Carson Davis
1974. Quaternary records of *Microtus xanthognathus* (Leach), the yellow-cheeked vole, from northwestern Arkansas and southwestern Iowa. Jour. Mammal. 55(3):640-645.

Hall, E. Raymond, and Keith R. Kelson
1959. The mammals of North America. The Ronald Press Co., New York. 2 vols. 1162 pp.

Hall, John S., and Charles H. Blewett
1964. Bat remains in owl pellets from Missouri. Jour. Mammal. 45(2):303-304.

Handley, Charles O., Jr.
1953. A new flying squirrel from the southern Appalachian Mountains. Proc. Biol. Soc. Washington. 66:191-194.
1956a. Bones of mammals from West Virginia caves. Amer. Midland Nat. 56(1):250-256.
1956b. The shrew *Sorex dispar* in Virginia. Jour. Mammal. 37(3):435.
1959. A revision of American bats of the genera Euderma and Plecotus. Proc. U. S. Natl. Mus. 110(3417):95-246.

———, and C. P. Patton
1947. Wild mammals of Virginia. Commonwealth of Virginia Comm. Game and Inland Fisheries. 220 pp.

Hawksley, Oscar, Jack F. Reynolds, and Robert L. Foley
1973. Pleistocene vertebrate fauna of Bat Cave, Pulaski County, Missouri. Bull. Natl. Speleo. Soc. 35(3):61-87.

Hay, Oliver P.
1920. Descriptions of some Pleistocene vertebrates found in the United States. Proc. U. S. Natl. Mus. 58(2328): 83-146.
1923. The Pleistocene of North America and its vertebrated animals from the states east of the Mississippi River and from the Canadian provinces east of longitude 95°. Carnegie Inst. Wash. 499 pp.

Hibbard, Claude W.
1949. Techniques of collecting microvertebrate fossils. Contrib. Mus. Pal. Univ. Mich 8:7-19.

Hibbard, Foy N.
1941. Climate of Virginia. U. S. Dept. Agric. Yearbook, Climate and Man. pp. 1159-1169.

Holman, J. Alan
1967. A Pleistocene herpetofauna from Ladds, Georgia. Bull. Georgia Acad. Sci. XXV(3):154-166.

Holsinger, John R.
1964. The biology of Virginia caves. *In* Douglass, Henry H., ed., Caves of Virginia, Va. Region Natl. Speleo. Soc., Virginia Cave Survey, Falls Church. pp. 57-74.

Howell, Arthur H.
1918. Revision of the American flying squirrels. N. Amer. Fauna. 44:1-64.
1929. Revision of the American chipmunks. U. S. Dept. Agric. N. Amer. Fauna. 52:157.
1932. Florida bird life. Fla. Dept. Game and Freshwater Fish. xxiv + 579 pp.

Jackson, Hartley H. T.

1928. A taxonomic review of the American long-tailed shrews. N. Amer. Fauna. 51:238 pp.

Johnson, David H.
1950. *Myotis subulatus Leibii* in Virginia. Jour. Mammal. 31(2):197.

Jones, J. Knox, Jr., Dilford C. Carter, and Hugh H. Genoways
1975. Revised checklist of North American mammals north of Mexico. Occas. Papers, Mus. Texas Tech Univ. No. 28, 7 March. 14 pp.

Keener, Carl S.
1970. The natural history of the mid-Appalachian Shale Barren flora. *In* Holt, Perry C., ed., The distributional history of the biota of the southern Appalachians, Part II: Flora. pp. 215-248.

Klimkiewicz, M. Kathleen
1970. The taxonomic status of the nominal species *Microtus pennsylvanicus* and *Microtus agrestis* (Rodentia:Cricetidae). Mammalia, Tome 34, No. 4:640-665.

Kretzoi, M.
1962. Arvicolidae oder Microtidae? Vertebrata Hungarica, Tom. IV. Fasc. 1-2. pp. 171-175.

Kurten, Bjorn, and Elaine Anderson
1972. The sediments and fauna of Jaguar Cave: II—The Fauna. Tebiwa, Jour. Idaho State Mus. 10(1):26-36.

Latham, R. M.
1950. The food of predaceous animals in northeastern United States. Final report, Pittman-Robertson Proj. 36-R. Report 1, Pa. Game Comm., Harrisburg, Pa. 69 pp.

Lensink, Calvin J.
1954. Occurrence of *Microtus xanthognathus* in Alaska. Jour. Mammal. 35(2):259.

Linzey, Alicia V., and Donald W.
1971. Mammals of Great Smoky Mountains National Park. Univ. of Tenn. Press. 114 pp.

Lipps, L., and C. E. Ray
1967. The Pleistocene fossiliferous deposit at Ladd's, Bartow County, Georgia. Bull. Georgia Acad. Sci. 25:113-119.

Long, Charles A
1972a. Taxonomic revision of the mammalian genus *Microsorex* Coues. Trans. Kansas Acad. Sci. 1971/74 (2):181-196.
1972b. Notes on habitat preference and reproduetion in pygmy shrews, *Microsorex*. Canadian Field-Naturalist, 86: 155-160.
1974. *Microsorex hoyi* and *Microsorex thompsoni*. Amer. Soc. Mammalogists. Mammalian Species No. 33:1-4.

Lynch, John D.
1966. Additional treefrogs (Hylidae) from the North American Pleistocene. Ann. Carnegie Mus. 38(11):265-271.

MacCord, Howard A., Sr.
1973a. The Hirsh Site. Archeol. Soc. Va., Q. Bull. 27(3):151-157.
1973b. The Hidden Valley Rockshelter, Bath County, Virginia. Archeol. Soc. Va. Q. Bull. 27(4):198-228.

McKeon, John B.
1974. Letter to the editor. Science. 184:88-89.

Martin, Robert A.
1974a. Fossil mammals from the Coleman IIA fauna, Sumter County. *In* Webb, S. David, ed., Pleistocene Mammals of Florida. pp. 35-99.
1974b. Late Pleistocene mammals from the Devil's Den fauna, Levy County. *In* Webb, S. David, ed., Pleistoeene Mammals of Florida. pp. 114-145.

Martin, Robert L.
1973. The dentition of *Microtus chrotorrhinus* (Miller) and related forms. Occas. Papers, Univ. Conn., Biological Sci. Ser. 2(12):183-201.

Maxwell, Jean A. and Margaret Bryan Davis
1972. Pollen evidence of Pleistocene and Holocene vegetation on the Allegheny Plateau, Maryland. Quat. Res. 2(4): 506-530.

Mayer, W. V.
1941. Variation and systematic position of the flying squirrel of Idaho. Murrelet, 22:30-31.

Michels, Joseph W., and Ira F. Smith, eds.
1967. A preliminary report of archaeological investigations at the Sheep Rock Shelter site, Huntingdon, Pennsylvania. 2 vols. 943 pp.

Miller, G. S. Jr., and G. M. Allen
1928. The American bats of the genera *Myotis* and *Pizonyx*. Bull. U. S. Natl. Mus. 144:1-218.

Munro, J. A.
1929. Notes on the food habits of certain raptors in British Columbia and Alberta. Condor, XXXI:116.

Murray, J. J.
1945. The faunal zones of the Southern Appalachians. The Raven, 16(3-4):10-22.
1952. A check-list of the birds of Virginia. Va. Soc. Ornithol., pp.1-113.

Pagels, John F., and Cathy M. Tate
1975. Small Mammals of the Paddy Knob-Little Back Creek area of Bath County, Virginia. Proc. Va. Jour. Sci.,26(2): 59.,abstract.

Paradiso, John L.
1969. Mammals of Maryland. N. Amer. Fauna, No.66, 193 pp.

Parmalee, Paul W.
1967. A Recent cave bone deposit in southwestern Illinois. Bull. Natl. Speleo. Soc. 29 (4):119-147.

Parmalee, Paul W., and John E. Guilday
1966. A Recent record of porcupine from Tennessee. Jour. Tenn. Acad. Sci.,41(3):81-82.

Parmalee, Paul W., Ronald D. Oesch, and J. E. Guilday
1969. Pleistocene and Recent vertebrate faunas from Crankshaft Cave, Missouri. Ill. State Mus. Reports of Investigations, No.14: 1-37.

Peterson, O. A.
1926. The fossils of the Frankstown Cave, Blair County, Pennsylvania. Ann. Carnegie Mus.,16(2): 249-315.

Preble, Edward A.
1908. A biological investigation of the Athabaska-Mackenzie region. N. Amer. Fauna No.27. 574 pp.
1910. A new *Microsorex* from the vicinity of Washington, D.C., Proe. Biol. Soc. Wash., 23, 24 June: 101-2.

Quinn, J. H.
1972. Extinct animals in Arkansas and related C-14 dates circa 3000 years ago. 24th Inter. Geol. Congr.12: 89-96.

Ray, Clayton E.
1965. A new chipmunk, *Tamias aristus*, from the Pleistocene of Georgia. Jour. Paleont. 39(5):1016-1022.
1967. Pleistocene mammals from Ladds, Bartow County, Georgia. Bull. Georgia Acad. of Sci. XXV(3):120-150.

Ray, Clayton E., Byron N. Cooper, and William S. Benninghoff
1967. Fossil mammals and pollen in a late Pleistocene deposit at Saltville, Virginia. Jour. Paleont. 41(3).

Ray, Clayton E., Charles S. Denny, and Meyer Rubin
1970. A peccary, *Platygonus compressus* LeConte, from drift of Wisconsinan age in northern Pennsylvania. Amer. Jour. Sci., 268(1):78-94.

Repenning, Charles A.
1967. Subfamilies and genera of the Sorieidae. Geol. Surv. Prof. Paper 565, U. S. Gov. Print. Office, Wash., D. C. 74 pp.

Rhoads, Samuel N.
1903. The mammals of Pennsylvania and New Jersey. Privately printed. Philadelphia. 266 pp.

Roberts, Harvey A., and Robert C. Early
1952. Mammal survey of southeastern Pennsylvania. Pa. Game Commission, Harrisburg. 70 pp.

Saltzman, Barry, and Anandu D. Vernekar
1975. A solution for the Northern Hemisphere climatic zonation during a glacial maximum. Quat. Res. 5(3):307-320.

Semken, H. A.
1969. Paleoecological implications of micromammals from Peccary Cave, Newton County, Arkansas. Abstr. Program mtg. Geol. Soc. Amer., 3:27.

Shane, Orrin C., III, and Paul W. Parmalee
[In press] Vertebrate remains from the Raven Rocks site, Belmont County, Ohio. Kent State Univ. Press.

Shay, C. Thomas
1971. The Itasca Bison Kill site, an ecological analysis. Minn. Hist. Soc. 133 pp.

Smith, Charles R., Jack Giles, M. E. Richmond, Jerry Nagel, and D. W. Yambert
1974. The mammals of northeastern Tennessee. Jour. Tenn. Acad. Sci. 49(3):88-94.

Soper, J. D.
1942. Mammals of Wood Buffalo Park, Northern Alberta and District of Mackenzie. Jour. Mammal. 23(4):119-145.
1948. Mammal notes from the Grande Prairie-Peace River region, Alberta. Jour. Mammal. 29(1):49-64.

Todd, W. E. Clyde
1963. Birds of the Labrador Peninsula and adjacent areas. Univ. Toronto Press. 819 pp.

Vazquez, A. W.
1956. A new southern record for *Mustela erminea cicognanii*. Jour. Mammal. 37:113-114.

Voorhies, M. R.
1974. Pleistocene vertebrates with boreal affinities in the Georgia Piedmont. Quat. Res. 4(1):85-93.

Watts, W. A.
1970. The full-glacial vegetation of northwestern Georgia. Ecology. 51(1):17-33.

Weigel, Robert D.
1974. Investigations in Russell Cave. Part 5: vertebrates from Russell Cave. Publ. Archeol., Natl. Park Serv., U. S. Dept. Inter. 13:81-85.

Wetmore, Alexander
1959. Notes on certain grouse of the Pleistocene. Wilson Bull. 71(2): 178-182.
1967. Pleistocene aves from Ladds, Georgia. Bull. Georgia Acad. Sci. XXV(3):151-153.

Wilder, C. D. Jr., and R. D. Fisher
1972. Occurrence of the golden mouse in southwestern Virginia. Chesapeake Sci. 13(4):326-327.

Wrigley, Robert E.
1972. Systematics and biology of the woodland jumping mouse, *Napaeozapus insignis*. Ill. Biol. Monogr. 47. Univ. Ill. Press. 117 pp.

Youngman, Phillip M.
1975. Mammals of the Yukon Territory. Natl. Mus. Can., Ottawa 1975; Publ. in Zool., 10:1-192.